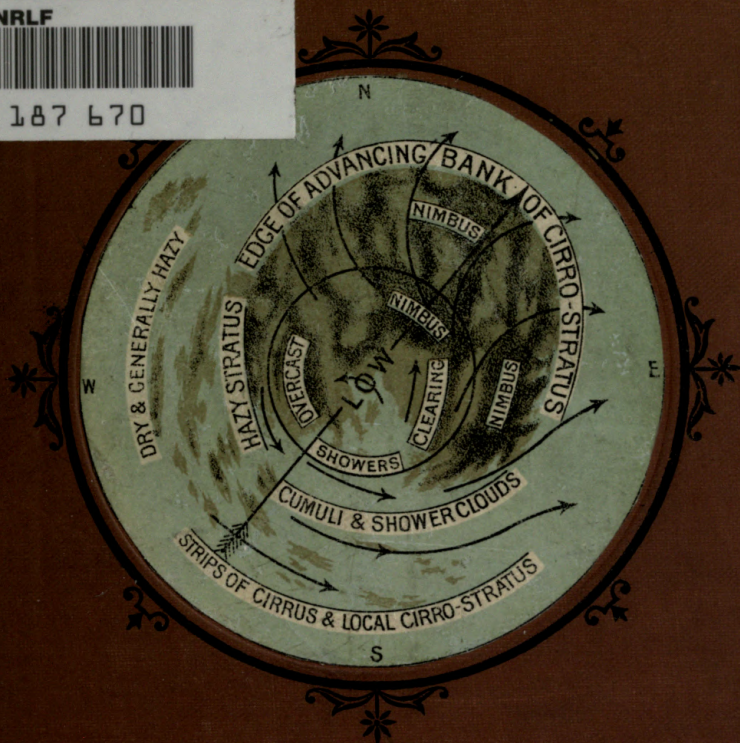


WEATHER CHARTS AND STORM WARNINGS

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ROBERT H. SCOTT, M.A. F.R.S.





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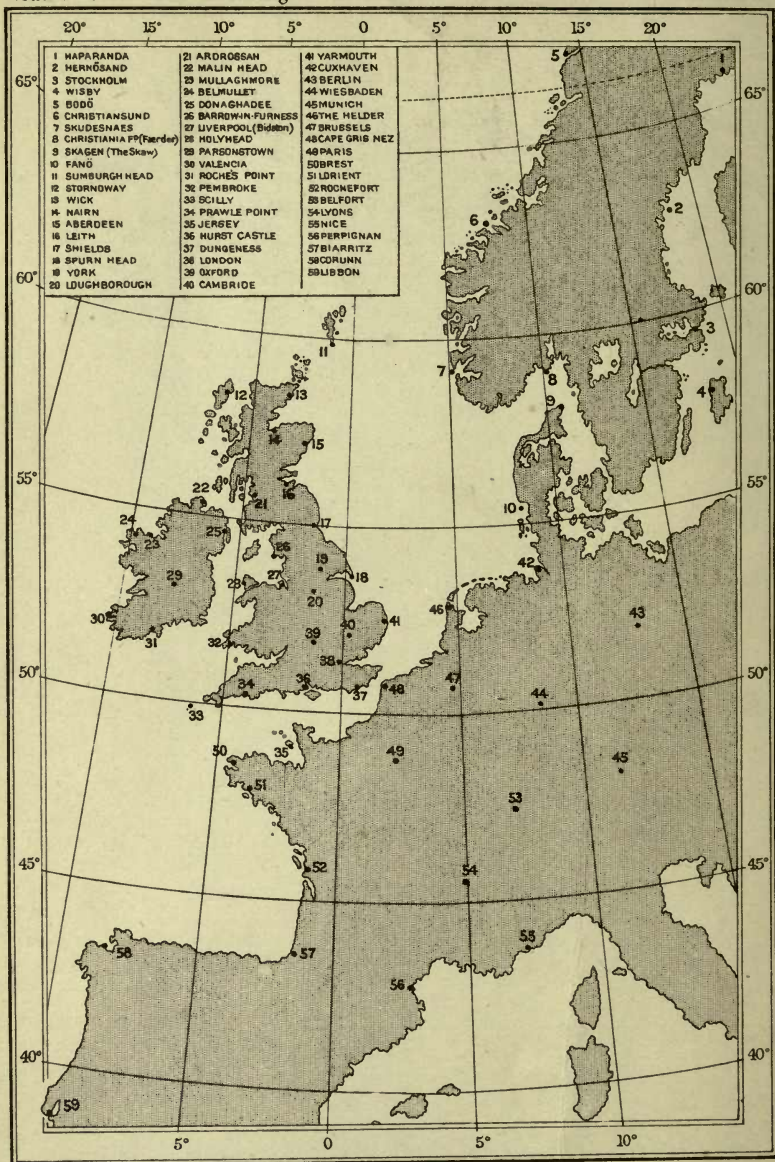


CHART SHEWING THE POSITION OF THE TELEGRAPHIC REPORTING STATIONS.
January 1887.

WEATHER CHARTS
AND
STORM WARNINGS

BY

ROBERT H. SCOTT, M.A., F.R.S.

SECRETARY TO THE METEOROLOGICAL COUNCIL

WITH NUMEROUS ILLUSTRATIONS

THIRD EDITION, REVISED AND ENLARGED

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B. D.

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1887

PREFACE TO THE THIRD EDITION.



THE second edition of this book having been long out of print, I have been requested by several friends to prepare a new edition.

The entire text has been revised, and some new chapters have been added, mainly relating to changes and improvements in the Office weather work since the year 1876.

The subjects of the new chapters are, the Distribution and Periodicity of Gales, Weather Forecasting, the Weekly Weather Report, and lastly, Cirrus Cloud Observations. The subject of 'Suggestions for Improvement,' formerly included under 'Storm Warnings,' has been made a separate chapter. The chapter on the Weekly Weather Report contains an account of the

method of calculating 'Accumulated Temperature,' in use in the preparation of that Report.

Chapter XIII., 'On Cirrus Cloud Observations,' is of the nature of an Appendix to the book, but it has seemed best to constitute it a separate chapter.

ROBERT H. SCOTT.

METEOROLOGICAL OFFICE:

July 25, 1887.

PREFACE TO THE FIRST EDITION.

THIS little work has been put together in the endeavour to supply a want which has been expressed in many quarters: that of an explanation of the weather charts which appear in the newspapers, and of the remarks which are appended to them.

The conceptions and principles on which the science of weather study is based are apparently quite new to the majority of ordinary readers, who still hold to the belief that the barometer rises or falls in direct relation to the weather, without any attempt to consider *how* or *why* it does so.

It is hoped that the following pages may convey some idea, however imperfect, of the present state of Weather Knowledge, as distinguished from the science of Meteorology itself, of which this book makes no claim to be called a manual.

With a very few exceptions, theories of the causes of storms have been left unnoticed, as the object has been

to explain to the reader what he can learn from a careful study of the information published in the newspapers or in the Daily Weather Reports, and which is therefore accessible to all.

In treating of a science now in process of rapid development, it can only be expected that every year will add to our knowledge, and that many of the principles stated in these pages will be extended or modified by the results of subsequent experience. All that it is here attempted to give to the public is an account of the actual state of our knowledge at present.

I must express my sincere thanks to several friends who have aided me with their advice during the preparation of the book, and most notably to Mr. Frederic Gaster, of this Office.

The illustrations which are contained in the text have all been executed by the Patent Type Founding Company, by the same process as they employ for the production of charts for newspapers.

ROBERT H. SCOTT.

METEOROLOGICAL OFFICE :

June 10, 1876.

CONTENTS.



CHAP.	PAGE
I. THE MATERIALS AVAILABLE FOR WEATHER STUDY	I
II. THE WIND	23
III. THE BAROMETER	32
IV. GRADIENTS	44
V. CYCLONES AND ANTICYCLONES	57
VI. THE MOTION OF STORMS AND THE AGENCIES WHICH APPEAR TO AFFECT IT	87
VII. THE USE OF WEATHER CHARTS	109
VIII. THE DISTRIBUTION AND PERIODICITY OF GALES	126
IX. STORM WARNINGS	137
X. FORECASTING	162
XI. SUGGESTIONS FOR IMPROVEMENT	178
XII. THE WEEKLY WEATHER REPORT	193
XIII. ON CIRRUS CLOUD OBSERVATIONS	207



APPENDICES.

A. WEATHER REPORT. NOVEMBER 29, 1874	218
B. READINGS OF AUTOMATIC INSTRUMENTS. VALENCIA, MARCH 26, 27, 1874	221
C. READINGS OF AUTOMATIC INSTRUMENTS. ABERDEEN, OCTOBER 20, 21, 1874	222
D. READINGS OF AUTOMATIC INSTRUMENTS. FALMOUTH, FEBRUARY 1, 2, 1873	223

PLATES.

- I. CHART SHOWING THE POSITION OF THE TELE-
GRAPHIC REPORTING STATIONS, JANUARY 1876 . *to face Title*
- II. CLOUDS AND WEATHER IN A CYCLONIC SYSTEM,
ACCORDING TO CLEMENT LEY *to face p. 65*
- III. WEATHER CHARTS, NOVEMBER 29, 1874, 8 A.M.
(REDUCED FROM THE DAILY WEATHER REPORT) . *to face p. 220*

WEATHER CHARTS AND STORM WARNINGS.

CHAPTER I.

ERRATA.

- ✓ P. 46, diagram, *insert* “.02” *before* “C.”
- ✓ „ line 6 *ab infra*, *for* “5” *read* “10.”
- ✓ P. 194, at head of table *insert* “Figures for week ending
April 25, 1887.”

and omitting technical descriptions of the instruments
themselves.

The observations taken at these stations refer to
Atmospherical Pressure, Temperature, Humidity (or the
Dampness of the Air), Wind, Rain, Weather, and, at sea-
coast stations, Sea Disturbance.

The drawing of weather charts depends on the com-

PLATES.

I. CHART SHOWING THE POSITION OF THE TELE-

WEATHER CHARTS AND STORM WARNINGS.

CHAPTER I.

THE MATERIALS AVAILABLE FOR WEATHER STUDY.

BEFORE proceeding to describe the charts themselves, or to give an account of their utility in aiding us to form a judgment as to probable weather, it will be well to explain the character of the observations and the nature of the service on which they are based, confining ourselves exclusively to the instruments employed and observations taken at our own telegraphic reporting stations (the outfit of which is necessarily less complete than that of a fully furnished meteorological observatory), and omitting technical descriptions of the instruments themselves.

The observations taken at these stations refer to Atmospheric Pressure, Temperature, Humidity (or the Dampness of the Air), Wind, Rain, Weather, and, at sea-coast stations, Sea Disturbance.

The drawing of weather charts depends on the com-

parison of various observations taken at the same time, at several different stations. It is therefore indispensable, that all the observations to be compared should be freed, as far as possible, from incidental inaccuracies and discrepancies, by reducing the conditions at each place to common standards of comparison, and this is done by applying the several instrumental and other corrections.

Atmospherical pressure is measured by the barometer, and by this is meant the mercurial barometer; for the aneroid, however convenient it may be for ordinary use as a weather glass, cannot be recognised as an independent instrument, its indications depending entirely on the delicacy of the mechanical appliances employed in its construction.

The barometer has a thermometer attached to it, in order to show the temperature of the instrument itself, and this must be read whenever an observation of the height of the mercurial column is taken.

The readings of the barometer are always said to be 'corrected and reduced to 32° and to sea-level,' and it is necessary to explain these expressions.

'Corrected,' means that corrections have been applied, *a*, for the error of the scale of the instrument, which has been ascertained by sending it for verification to some recognised establishment, such as Kew Observatory.

b, for what is called 'capillarity,' which depends on the bore of the tube, and

c, for what is called 'capacity,' which depends on

the proportion which the bore of the tube bears to the sectional area of the cistern.

'Reduced to 32° ,' means corrected according to the reading of the attached thermometer. The column of mercury in the barometer tube behaves like almost all other bodies, being lengthened by heat, and shortened by cold. It is therefore obvious that unless two similar barometers be precisely at the same temperature, they cannot possibly read alike, and hence is apparent the absolute necessity of reducing all readings to one common temperature; for this the temperature of melting ice, 32° F., has been unanimously adopted as the best.

The temperature of the column being indicated by the reading of the attached thermometer, we can discover, by means of printed tables, how much, for each reading of that thermometer, the column is longer, or shorter, than it would be at 32° , and consequently what correction is required for the barometer reading.

'Reduced to sea-level,' is a phrase which requires rather more explanation than the foregoing. The barometer, as its name implies, measures the weight of the air, and that weight, of course, depends mainly on the quantity of air which is above the instrument pressing upon the cistern, and keeping up the column of mercury in the tube. If, therefore, two similar barometers be placed one directly under the other, say, one in the attic, and the other on the ground-floor, it is evident that there will be a less quantity of air above

the former than above the latter instrument, and, consequently, the barometer in the attic will read lower than that on the ground-floor.

Precisely the same reasoning will apply if we are considering two barometers at different heights on the side of a mountain, or one at an inland station, and the other at the level of the sea; in every instance the barometer at the higher station will read lower than that at the lower.

Hence we find that all readings must be reduced to their equivalent readings at a standard elevation, as well as at a standard temperature. This standard elevation is the Mean Level of the Sea, and the reduction is carried out by means of tables.

A slight consideration of the foregoing remarks, and of the last-named principle in particular, will show how it comes about that the reading given in a Daily Weather Report for an inland station, like Oxford, or Nottingham, can never agree with a casual reading taken by an observer at either of those stations at the same time, unless the latter reading be corrected and reduced to 32° , and to sea-level. It must, however, be remembered that the problem of the reduction to sea-level is not so very simple. Its correctness depends on the accuracy of the knowledge we possess of the temperature of the supposed column of air extending from the level of the upper station to that of the lower. Now if the height of this column be considerable, our knowledge of this temperature cannot be complete, and therefore for

elevations above one thousand feet, the reduction by the tables is not quite exact. Accordingly, for such stations as that on Ben Nevis, at the height of 4000 feet, the reduction of the readings to sea-level by tables is not very generally accepted.

Temperature.—This does not require much explanation. In addition to the actual readings of the thermometers, 'in the shade' (*i.e.*, suspended in a properly constructed louvre-boarded screen at a height of four feet above the ground), which are taken at certain definite hours, the Daily Weather Reports give also two columns, showing, respectively, the maximum and minimum readings taken during the twenty-four hours, ending at 8 o'clock each morning, by thermometers so constructed as to register, one the highest, and the other the lowest, temperature reached during the interval which has elapsed since the last setting.

The last-named readings may also be turned to very useful purpose. The mean temperature of the day is often mentioned in connection with sanitary statistics, as for instance in the Registrar-General's Reports. This mean temperature is theoretically the average of twenty-four thermometer readings taken at hourly intervals during the day. There are well-known rules for determining this mean temperature out of various combinations of hours of observation. The simplest method, and, for practical purposes, nearly the most exact, is to take the average of the maximum and minimum readings given in the Daily Weather Report,

6 *Weather Charts and Storm Warnings.*

on any day, and put that down as the mean temperature of the preceding day.

Humidity.—The amount of moisture in the air is measured by the indication of a thermometer with its bulb encased in muslin, and kept damp (a wet bulb), compared with that of an ordinary (dry bulb) thermometer, without any such mounting, observed at the same moment. Tables exist from which the amount of moisture for each observed difference in readings between the two thermometers can be ascertained.

This is not the place to enter into the theory of these observations. Suffice it to say, the greater the difference between the readings of the two thermometers the drier is the air, and that when the two thermometers read alike, the atmosphere is exceedingly damp. The difference between the two thermometers ranges in this country from 0° to 10° or even 15° , and sometimes a difference of upwards of 20° has been noticed.

The chance of rain depends to a great extent on the degree of humidity of the air from time to time, and if we are dealing with reports from an extensive tract of country, as North America, or the Continent of Europe, the distribution of the moisture is an interesting subject of study. As regards these islands, the fact that most of the telegraphic stations are on the sea-coast detracts from the value of the reports of humidity, inasmuch as the amount of moisture in the air is seriously affected by proximity to the sea ; and so in weather study we are unable to use reports of vapour tension as much as our neighbours.

Rain is measured by means of a rain-gauge. The values given represent the depth of water which would have accumulated on a level piece of ground, if none of the rain which fell had escaped by drainage, &c. Too much faith must not be placed on the rain returns in the daily reports, for two reasons. Firstly, the gauges are often necessarily placed in towns, where a good exposure is not to be had, so that the amount measured is not the same as might be yielded by a gauge in a more open situation; and secondly, the telegraphic stations are so sparsely distributed over the kingdom that it is impossible that they can give a precise account of the rainfall in every county. What they do show is whether or not the rain is general and heavy.

Wind.—As a general rule, for the purposes of the Daily Weather Report, wind is not measured by an instrument, but is simply estimated according to the Beaufort scale, which is so named after the late Admiral Sir Francis Beaufort, who devised it for his own use, when in command of H.M.S. *Woolwich* in 1805. The following is the scale,¹ with the approxi-

¹ Since Admiral Beaufort's time there has been a great change in the rig of ships by the introduction of double topsail yards. It seems therefore advisable to add to Beaufort's scale the amount of sail which his ship would have been able to carry, had she been rigged with double topsail yards, but under all other circumstances the same. The change would only affect forces 6 to 10.

6. Topgallant sails.
7. Topsails, jib, &c.
8. Reefed upper topsails and courses.
9. Lower topsails and courses.
10. Lower maintop-sail and reefed foresail.

8 *Weather Charts and Storm Warnings.*

mate equivalent velocity of the wind in miles per hour, for each grade as determined in the Meteorological Office.

			Miles per hour
0. Calm			3
1. Light air	Or, just sufficient to give steerage way		8
2. Light breeze	Or, that in which a well-conditioned man-of-war, with all sail set, and 'clean full,' would go in smooth water from	1 to 2 knots	13
3. Gentle breeze		3 to 4 knots	18
4. Moderate breeze		5 to 6 knots	23
5. Fresh breeze	Or, that to which she could just carry in chase, 'full and by'	Royals, &c.	28
6. Strong breeze		Single-reefed topsails and topgallant sails	34
7. Moderate gale		Double-reefed topsails, jib, &c.	40
8. Fresh gale	Or, that which would reduce her to storm-staysails	Triple-reefed topsails, &c.	48
9. Strong gale		Close-reefed topsails and courses	56
10. Whole gale	Or, that with which she could scarcely bear close-reefed maintop-sail and reefed foresail		65
11. Storm	Or, that which would reduce her to storm-staysails		75
12. Hurricane	Or, that which no canvas could withstand		90

It is obvious that as this scale refers to the rate of sailing of, or to the amount of sail carried by, a ship, it is at first sight not well suited for use at land stations ; but experience has shown that the reporters, guided by the descriptions in the second column, are never very far from the truth in their estimates, when once they have gained some practice in observing. There are objections to supplying instruments for the measurement of wind to telegraphic stations, owing to the great difficulties which would be experienced in erecting them in suitable positions. Anemometrical indications taken in the middle of a town are almost worthless, as the

buildings produce such eddies that the true movement of the air cannot be ascertained from the instrument.

As regards the numbers of the Beaufort scale, it is those from 6 upwards which present the most interest. 6 is the lowest number which is taken in the Meteorological Office to justify the issue of a warning to the coast, and 9 is the lowest figure which by the regulations of the Board of Trade can be pleaded by a captain as 'stress of weather,' in case of casualty to his craft. These velocities are not uniform, like that of an express train. The statement of 56 miles an hour, means 56 miles in the hour, but during that hour the wind may have been gusty, and at times have had a velocity of nearly 100 miles an hour, while at other times its hourly speed may have scarcely reached 30 or 40 miles.

It may be remarked that if we employed the pressure, instead of the velocity of the wind, to measure the violence of a gale, we should be able to obtain a record of individual gusts, and in the opinion of many persons, such as engineers, &c., such information would be more practically useful to the public, than statements as to velocity. The reason that pressure anemometers are not generally adopted is, that as yet it has not been found possible to reason with sufficient confidence as to the pressure of the wind on a structure, such as a factory chimney, from the indications shown by a pressure plate of, say, one square foot in area. Till the influence of the size of the pressure plate on its indica-

tions, in a wind of given strength, has been thoroughly determined, it seems premature to recommend the employment of pressure anemometers.

Weather.—The various observations which are comprehended under this general term are those which do not admit of instrumental record, such as the fact of the occurrence of thunder, &c. These are reported according to the subjoined notation, which, like the wind scale, is due to Sir F. Beaufort.

<i>b</i> Blue sky, whether with clear or hazy atmosphere.	covered with an impervious cloud.
<i>c</i> Cloudy, but detached opening clouds.	<i>p</i> Passing temporary showers.
<i>d</i> Drizzling rain.	<i>q</i> Squally.
<i>f</i> Foggy.	<i>r</i> Rain, continued rain.
<i>g</i> Dark gloomy weather.	<i>s</i> Snow.
<i>h</i> Hail.	<i>t</i> Thunder.
<i>l</i> Lightning.	<i>u</i> 'Ugly,' threatening appearance of the weather.
<i>m</i> Misty hazy atmosphere.	<i>v</i> 'Visibility,' whether the sky be cloudy or not.
<i>o</i> Overcast, the whole sky being	<i>w</i> Dew.

The only thing to be remarked about the use of these letters in the Daily Weather Reports is that, when two or three are entered to the same place on the same day, it implies that the observations have been taken in the order in which they are printed. Thus *b.c.p.r.* would mean that, during the interval which had elapsed since the previous report, the sky was at first 'quite clear,' then 'detached clouds' came over it 'passing showers' ensued, at last turning to persistent 'rain' which 'continued' at the time of sending off the telegram.

Sea Disturbance.—Lastly, the table contains a column for the Sea Disturbance, of which there are nine grades, depending on estimation, like the scale for wind force.

- | | |
|-----------------|------------------|
| 0. Dead calm. | 5. Rather rough. |
| 1. Very smooth. | 6. Rough. |
| 2. Smooth. | 7. High. |
| 3. Slight. | 8. Very high. |
| 4. Moderate. | 9. Tremendous. |

The height of the waves not unfrequently gives valuable information as to the force of the wind in the offing, but we must not place too much dependence on this particular indication, for many of our most serious storms have come on without any previous disturbance of the sea on our coast. This is due to the fact that the sea disturbance is caused by the wind outside, and if that wind is not blowing in the direction of a coast, it will not impel waves towards that coast. It will presently appear how a wind may advance to a coast without blowing towards it, but for the present it may be said, that the fact of a wind blowing in the direction of these islands, and driving a heavy sea on to parts of our coasts, is no positive proof that the wind itself will ever be felt on our shores. In fact, some of the heaviest seas reported on our western coasts are proved to have been caused by Westerly gales blowing far out in the Atlantic, which never reached Europe at all.

There are yet other remarks to be made as to the sea disturbance column, which is, after all, a portion of

our table often consulted anxiously by such landmen and landswomen as may have to cross the Channel. In the first instance, the sea close in shore, at a place like Dover, is often much calmer than it is outside, as that harbour is sheltered from several winds, especially Northerly ones. Secondly, the roughness of the sea depends in great measure on the direction in which the tide is running at the time of observation. 'Wind against tide' knocks up a sea at once, and frequently the delay of a few hours may make all the difference between the miseries of sea-sickness, and the enjoyment of perfect comfort, if the tide has changed in the interval.

These, then, are the materials with which we have to deal in drawing charts, discussing weather, preparing forecasts, and in sending warnings to the coast, and it is self-evident that they are far from complete.

It is obvious that the amount of information as to the appearance of the weather at each station which can be conveyed by the three or four letters which, at most, are given in the proper column, is quite insufficient to convey to our minds any clear idea of what an experienced person would have gathered as to the general character and prospects of the weather at that station; and yet the general appearance of the weather was all that our fishermen and pilots had to guide them for generations, nay, for centuries, before the barometer was invented. Right well did they then,

and do their successors now, know how to profit by such signs !

In the first place, the code is necessarily so condensed that it cannot give information as to the form of clouds, whether these be the highest 'mare's tail' or the lowest rain cloud, or whether there be more than one stratum. The value of such particulars for the purposes of weather study need hardly be mentioned. The character of the clouds, their changes, and their amount, afford to the practised eyed most valuable information as to the condition of the atmosphere above us. Moreover, the code does not tell us anything about the motion of the clouds, so often the truthful indication of coming wind, though we do endeavour to obtain, by means of words added to the telegrams, information on this motion, when there is anything remarkable in it.

By the researches mainly of the Rev. W. Clement Ley in this country, and of Professor Hildebrandsson in Sweden, certain principles for the interpretation of cloud motion have been established. A brief *résumé* of these will be given in Chapter XIII.

In these and all such particulars, the Weather Telegrams, no matter how correct they may be, are only a poor substitute for actual personal observation. Any one trying to form a correct judgment of the look of the sky from these alone is like a physician trying to deal with a case without a chance of a personal interview with his patient. What can a resident in an inland

town like London know of the appearance of the weather on the sea-coast on any day from any telegram, no matter how detailed?

The reports are therefore incomplete as to quality and quantity, but in many respects they are capable of material improvement, especially if it should ever be rendered possible to devote more money to the service.

As to quality, the instruments *should* be automatic, so that by looking at the record traced mechanically, we should be able to notice all that had passed since the last observation. Of late years automatic aneroids have been introduced at some of the most important stations, and have been found to be of considerable service. The reporters *should* be experienced observers, with outdoor occupations, so as to be constantly on the look-out for any change of weather which may take place, and therefore they should be selected from such a class of men as signalmen on the coast. It is obvious that such a weather report as can be given by a clerk who simply runs out to look at the sky just before filling up his despatch, cannot be of as much value as that of a man who has been in the open air watching the weather for an hour or so, or even for the better part of the day. As to quantity also, the reports are not sufficiently complete, both as regards time and space.

As regards time, they are not nearly frequent enough. The Signal Office at Washington receives three reports every day from each of its stations; but, as is well

known, that office is most liberally supplied with funds by Congress. Our own Meteorological Office, however, can only afford one at 8 A.M. from most of our stations, and at best we only get additional reports at 2 P.M. and at 6 P.M. from a limited number of places. As regards Sunday mornings, the service is necessarily much hurried, for the telegraph offices are, as a rule, only open from 8 to 10 A.M., and there is no service at 2 P.M. at all. On Sunday evenings, however, the service is the same as on week-days.

Lastly, as to space, the area over which our own network and our international exchange extends, is far too limited for us to gain a general idea of the conditions which are prevailing all around us, and it is on these that our weather in great measure depends. This might, to a certain extent, be remedied by an extension of our Continental communications, but, as will be pointed out later on, the information obtainable from Europe is comparatively unimportant when contrasted with what we can supply to our Continental neighbours. What we really want, to give us a better insight into our chances of weather from time to time, is unfortunately unattainable, and that is a system of reports from stations in the Atlantic, say, at a distance of 600 miles from our coasts, for most of our storms advance on us from the Atlantic. It is a problem as yet unsolved, to moor a vessel in 1000 fathoms water, and to connect her with the shore by a telegraphic cable. The experiment of a floating telegraphic station,

which was tried in 1869 at the entrance of the Channel, in much shallower water than 1000 fathoms, was not encouraging, as will be explained later (p. 181). It has, however, been recently proved by the Telegraph Construction and Maintenance Co. to be possible to maintain telegraphic communication with a light-ship.

Nevertheless, in spite of all the geographical defects of our insular position, and the difficulties which are unavoidable in the early stages of any branch of knowledge, satisfactory progress has been made in the science of Weather Telegraphy in these islands. When so much has been accomplished in the short space of a quarter of a century, since the service was first organised by Admiral FitzRoy in 1861, it may be hoped that with perseverance, and continued efforts to improve our methods, we shall one day arrive at some clearer knowledge of the laws of our storms and our weather.

The following is a specimen of the Daily Weather Report, as issued in January 1887. A chart showing the stations will be found as the Frontispiece.

The matter is exhibited on four lithographed pages. The contents of three of these are reproduced here. The fourth appears as Plate III., but the actual charts given there do not refer to January 1, 1887.

The Remarks on the General Situation at 8 A.M., and on the Weather over Europe during the past twenty-four hours, explain themselves.

The Forecasts will be explained in Chapter X.

It will be seen that in addition to the absent observations, which are marked with an asterisk, as is explained at foot of the table, various spaces are marked with dots (...), indicating that the report had not arrived for that day ; and others with notes of interrogation, indicating that for some reason or other the report appeared to be doubtful, in which case it is sometimes inserted and queried, and at others omitted altogether.

DAILY WEATHER REPORT, SATURDAY, JANUARY 1, 1887.

(For explanation of columns, see p. 20.)

18

Weather Charts and Storm Warnings.

STATIONS.	† YESTERDAY EVENING.					8 A.M. TO-DAY.					PAST 24 HOURS.				
	Barometer at 32° F. and Sea Level.	Temp. in Shade.	WIND.		Weather.	BAROMETER.	SHADE TEMP.			WIND.	Weather.	Sea. (0 to 9.)	SHADE TEMP.	Amount of Rainfall.	
			Direction.	Force. (0 to 12.)			Dry.	Wet.	Difference from 8 A.M. yesterday.						Direction.
SCANDINAVIA.	Haparanda	Ins.	6		0	Ins.	30.26	28	28	+13	S.	6	0	0	Ins.
	Hernösand	30.36	15	0	0	-06	30.46	12	12	+7	Z.	0	0	-4	...
	Stockholm	30.54	25	0	bc	+02	30.50	6	5	+1	Z.	0	0	5	...
	Wisby	30.56				Not received									...
	Bolö	30.14	39		q	29.95		42	40	+10	SSW.	6	0	?	...
	Christiansund.	30.27	34		b	-23	30.15	40	36	+5	ESE.	2	0	41	0.08
	Skudenes	30.47	37		o	-10	30.39	39	37	+4	SSE.	6	0	?	...
	Christiania Fjord														...
	(Færder)	30.57	19		f	.00	30.54	17	17	0	Z.	0	0	19	...
	Skagen (The Scaw)	30.58	26		o	-02	30.52	25	24	+1	SE.	1	0	27	...
BRITISH ISLANDS.	Fand	30.54	17		m	-07	30.46	24	24	+10	ESE.	2	0	27	...
	Sumburgh Head	30.16	43		r	-19	30.09	44	43	+5	S.	1	0	45	0.20
	Stornoway	30.15	45		r	-20	30.03	45	45	+3	SSW.	6	0	46	0.08
	Wick	30.17	40		r	-16	30.11	42	41	+3	SW.	2	0	42	0.18
	Nairn	30.21	41		r	-18	30.12	42	41	+3	SW.	2	0	43	0.01
	Aberdeen	30.32	38		o	-21	30.19	39	37	+6	SW.	2	0	41	...
	Leith	30.40	40		m	-20	30.26	41	39	+8	SW.	2	0	41	...
	Shields	30.49	32		q	-18	30.35	31	30	+2	SSW.	3	0	37	...
	Spurn Head	30.56	34		b	-11	30.44	30	28	-4	SSW.	2	0	37	...
	York	30.55	32		b	-15	30.41	23	23	-2	SSE.	1	0	34	...
	Loughborough	30.59	25		m	-11	30.47	17	17	-3	SSW.	1	0	30	...
	Ardrossan	30.39	42		o	-18	30.26	43	43	+5	SSW.	3	0	43	0.11
	Malin Head	30.25	41		o	-23	30.12	42	41	+2	SSW.	4	0	42	0.10
	Mullaghmore	30.30	45		o	-21	30.16	45	42	+1	SSW.	6	0	46	0.01

Station	S.	W.	46	30.28	41	5	0	30.12	-22	47	45	+2	SSW.	6	0	c	*	47	45	...
Belmullet			30.28																	
Donaghadee			30.42																	
Barrow-in-Furness.			30.49																	
Liverpool (Bidston)			30.52																	
Holyhead			30.49																	
Parsonstown			30.40																	
Valencia			30.38																	
Roche's Point.			30.43																	
Pembroke			30.47																	
Scilly			30.46																	
Prælle Point.			30.53																	
Jersey			30.48																	
Hurst Castle			30.55																	
Dungness			30.50																	
London			30.57																	
Oxford			30.59																	
Cambridge			30.58																	
Yarmouth			30.55																	
Cuxhaven			30.53																	
Berlin			30.43																	
Wiesbaden			30.25																	
Munich			30.25																	
The Helder			30.57																	
Brussels			30.50																	
Cape Gris Nez			30.40																	
Paris			30.40																	
Brest			30.50																	
Lorient			30.51																	
Rochefort			30.42																	
Belfort			30.48																	
Lyons			30.12																	
Nice			29.88																	
Perpignan			30.43																	
Blaritz			30.30																	
Corunna			*																	
Lisbon			30.12																	

† At Brixton the Maximum was only 30°.

20 *Weather Charts and Storm Warnings.*

YESTERDAY'S 2 P.M. REPORTS.

Stations.	Bar.	Dry.	Wet.	Wind.		Wea-ther.	Sea.
				Direc.	Force.		
Skudesnaes . . .	30.50	38	37	SSE.	6	rs	3
Sumburgh Head . .	30.21	42	40	S.	2	o	2
Stornoway . . .	30.19	44	44	S.	6	oqp	6
Aberdeen . . .	30.34	37	35	SSW.	6	c	2
Shields . . .	30.49	37	34	SW.	3	m	2
Ardrossan . . .	30.42	42	42	SSE.	4	o	3
Malin Head . . .	30.28	41	40	NW.	4	o	3
Mullaghmore . .	30.34	45	44	S.	5	op	3
Belmullet . . .	30.31	46	46	SSW.	3	o	*
Holyhead . . .	30.50	40	39	S.	2	b	2
Valencia . . .	30.40	47	46	SE.	6	rm	6
Scilly . . .	30.48	48	43	S.	2	bc	4
Dungeness . . .	?	39	36	?	5	bc	3
London . . .	30.56	37	34	NE.	1	bcf	*
Yarmouth . . .	30.55	38	36	ENE.	3	bv	4
Jersey . . .	30.49	41	37	ENE.	3	bc	3
Rochefort . . .	30.43	39	37	NNE.	7	b	2

EXPLANATION OF COLUMNS GIVEN ON P. 18.

WEATHER.—*Beaufort scale* is given on p. 10.

* *An asterisk* is inserted in all places for which information is not usually received.

† The evening observations are taken at 6 P.M. in France and our Islands, with the exception of Oxford, where they are taken at 8 P.M. In Sweden and Denmark, the observations are taken at 8 P.M. (Christiania time).

GENERAL SITUATION AT 8 A.M.

PRESSURE . . .	Highest, 30.5 inches and upwards over the South of Sweden.
	Lowest, 29.9 inches and less over the Gulf of Genoa, but relatively low, 30.0 inches and less, to the North-westward of our Islands and the Westward of Norway.
TEMPERATURE .	Highest, 48° at Valencia, 47° at Belmullet, 46° at Roche's Point, and 45° at Stornoway and Mullaghmore.
	Lowest, 6° at Stockholm, 12° at Hernösand, 14° at Cambridge, 15° at Oxford, and 20° at Munich.
	Hard frost prevailed last night over Central England, the lowest readings being 13° at Cambridge, 17° at Loughborough, and 22° in London.

The Materials available for Weather Study. 21

WIND	{ Light or moderate from NE. over Germany, France, the Netherlands, and the English Channel.
	{ Southerly elsewhere, strong in force on the West coasts of Ireland and Scotland.
WEATHER	{ Dull on our Western and Northern coasts, with drizzling rain at Stornoway.
	{ Fair in most other localities, but densely foggy over Central England and the Netherlands.
SEA	{ Rough at Stornoway and Valencia, but moderate to smooth elsewhere.

PROBABLE CHANGES IN SYSTEM NOW PREVALENT.

The anticyclone noticed over England and the North Sea yesterday appears to be still moving Eastwards, and the barometer is falling generally.

The depressions which are travelling along our Western coasts appear likely to advance closer to our shores, and a further increase of wind is probable over Ireland and Scotland.

No important change is likely at present over England beyond a gradual rise of temperature.

FORECASTS

FOR THE TWENTY-FOUR HOURS ENDING AT NOON ON
2ND JANUARY 1887.

Districts.	Forecasts.
*0. SCOTLAND, NORTH	Southerly and South-westerly winds, increasing in force ; cloudy, some rain.
*1. SCOTLAND, EAST .	Do. Do. Do.
2. ENGLAND, NE. .	Southerly winds, moderate, fair generally.
3. ENGLAND, EAST .	Same as No. 5.
4. MIDLAND COUNTIES	Same as No. 5.
5. ENGLAND, SOUTH .	Easterly and South-easterly winds, light ; foggy to fair.
*6. SCOTLAND, WEST .	South-easterly and Southerly winds, freshening ; cloudy, some rain.
7. ENGLAND, NW. .	Do. Do. Do.
8. ENGLAND, SW. .	Do. Do. Do.
*9. IRELAND, NORTH .	Southerly winds, strong, perhaps a gale, cloudy, some rain.
*10. IRELAND, SOUTH .	Do. Do. Do.

WARNINGS.—The South cone was hoisted last evening in districts 0, 6, 9, 10, and part of 1. An asterisk is inserted against those districts in which signals are now flying.

GENERAL REMARKS ON THE WEATHER OVER EUROPE
DURING THE PAST TWENTY-FOUR HOURS.

THE reports for yesterday showed that a large anticyclonic system had spread over the whole of Northern and North-western Europe, its centre being over the Eastern parts of the British Isles and the North Sea, where the barometer at 8 A.M. stood at a little above 30.5 inches. In the West and North-west of our Islands, however, the mercury had begun to fall steadily, while to the South-eastward of the high-pressure area readings decreased to 29.5 inches over the Adriatic. Thus, while South-westerly winds had set in over Ireland and Scotland, calms and variable airs were felt over England and the North Sea, and North-easterly to Northerly winds over the South of France and Northern Italy. The weather in the NW. and N. was dry, cold, and very foggy, while at the more Southern stations it was somewhat cloudy, with showers locally. Temperature was below the freezing-point at all but the most Western and Southern stations; over the Western and Southern parts of the Mediterranean it was still above 50°. The highest individual readings were 53° at Algiers, 52° at Malta, 51° at Brindisi, and 50° at Constantinople; the lowest, 5° F. at Hernösand, Stockholm, and St. Petersburg, 9° at Archangel, 14° at Helsingfors, 20° at Loughborough, 23° at Oxford, 26° at Cracow, 27° at Lemberg.

During the day the South-westerly winds in the West and North-west continued to blow steadily, but did not spread much over England, where dense fogs prevailed locally, and the night became very cold.

CHAPTER II.

THE WIND.

HAVING thus discussed the observations themselves, we come to the results and conclusions to be drawn from them, and, in order to make these intelligible, we must indulge in a little theorising, and refer to some things which, though not yet recognised as absolutely proved, appear at least probable, as regards the behaviour of the wind.

Every one knows that the East is very different in its character from the West wind, the former being reputed to be 'good neither for man nor beast.' Any one with a touch of bronchitis or rheumatism can (or at least *thinks* he can) tell you, without looking at a weather-cock, whether or not there is Easting in the wind. This contrast arises from the fact that as a rule the temperature and dampness of the air in Western Europe are both lowest when the wind is about North-east, and highest when it is about South-west. This is, however, a local phenomenon peculiar to certain parts of the globe, for if we travel from Western Europe, along the same parallel of latitude as our own,

either eastwards to the Sea of Ochotsk or westwards to Labrador, we shall find that in these districts the coldest wind is near North-west, and the warmest about South-east. In each case the coldest and driest point of the compass lies towards the region, in the neighbourhood of the point of observation, where the mean temperature is the lowest. In these islands, in winter, this region is northern Russia, in Labrador it is the Barren Grounds of the Hudson Bay Territory, and at the mouth of the Amur it is the district of Yakutsk. These two latter cold regions lie to the north-west of the respective coast districts to which reference has been made.

The wind, then, is cold and dry when it comes from a cold region, warm and moist when it comes from a warm district, such as, in these latitudes, the sea surface in winter. In summer there is not so strong a contrast between the temperature of different parts of the earth's surface and between land and water as in winter, and so the different winds do not differ so much in their characters.

In former years it was the fashion to say, that all cold winds flowed from the Poles to the Equator, forming the so-called Polar Currents, and becoming the Trade Winds when they approached the Tropics, while the warm winds flowed from the Equator to the Pole, forming the Equatorial Currents, or Anti-trades.

There can be no doubt that these statements were right in principle, as the original disturbing action

which produces motion in the atmosphere is the heat of the sun ; and this acts most strongly in the Torrid zone, which ought, accordingly, to be the region towards which all the cold air flowed, were it not for the irregular arrangement of land and water on the globe. Recent investigations have, however, shown that a body of air cannot be proved to have made its way direct from the Equator to either Pole, inasmuch as it will probably have been caught up on its way by some of the eddies and local circulations at all times existing on the earth's surface. The motions of the atmosphere are found to be regulated by the distribution of barometrical pressure over the globe, the particles moving from the regions where pressure is in excess—the barometer is high,—to those where pressure is in defect—the barometer is low,—and being modified in the direction of their motion by various causes, among which the earth's form, and its rotation on its axis, are the most influential.

We have said that a body of air cannot be proved to flow the whole way from the Equator to the Poles or back again, but nevertheless it is the fact that over extensive areas of the earth's surface the wind does maintain a constant direction for a considerable period of time. To prove this it is only necessary to cite the well-known phenomena of the Trade Winds and the Monsoons, where the wind blows persistently from the same direction, in one case for the whole year, and in the other for months at a time. In our own latitudes

the phenomena of the winds are not so regular, but yet it is found that over large tracts of Europe and the North Atlantic, the wind at times blows for weeks together in a definite direction, either Easterly or Westerly (speaking in general terms), and that these tracts, or the channels of these great currents, lie the one alongside the other. Occasionally very intense cold is experienced in winter over Central and Southern Europe, while these islands enjoy mild weather. It will be found that in such cases the winds are all Easterly where the weather is cold, and all Westerly where the weather is warm.

It will be explained subsequently how the motion of the air, both in direction and velocity, is regulated by the distribution of atmospherical pressure at the surface of the earth, which is shown by the distribution of the readings of the barometer in weather charts; but as this relation lies at the very foundation of the whole structure of modern weather knowledge, it will be useful, at the very outset, to explain it.

This principle, which, for convenience, is known as Buys Ballot's Law, from the name of the Dutch Professor who first stated it definitely, is contained in the following statement.

Stand with your back to the wind, and the barometer will be lower on your left hand than on your right.

These words hold good, except close to the Equator,

for the Northern hemisphere ; in the Southern we must interchange left and right. If this principle be once thoroughly recognised, the broad features of wind motion will be at once understood.

The *Force* of the wind, as distinguished from its *Direction*, is related to the amount of difference of barometrical pressure over a given distance, and this is defined as the 'gradient,' a term which will be explained in Chapter IV. (p. 44). This force therefore in no way depends on the absolute height of the barometer at any one station, as the words printed on the scales of many old-fashioned barometers would seem to indicate. In fact, as an illustration of this statement we may anticipate the future explanation by stating that at Liverpool, during a severe storm on January 24, 1876, from 2 till 3 A.M., the velocity of the wind from SW. was sixty-two miles within the hour, while the barometer was 30.10 inches, nearly at 'Set Fair.' Conversely, at 6 P.M. on March 9, 1876, the barometer at Wick read 27.94 inches, far below 'Stormy,' and the force of the wind was only 3 (a 'gentle breeze') from NW. In the one case, therefore, we had a heavy gale with a high barometer ; in the other, a gentle breeze with a very low barometer. The reason of these discrepancies between old theories and actual facts will appear when we treat of gradients.

Storms were formerly divided into two great classes—circular storms (hurricanes and typhoons) and straight-line storms. The former are almost the only class of

storms which occur within the tropics, and are known under the general name of cyclones. The latter class were formerly supposed to be the most usual type of storms in these latitudes, inasmuch as it is a common observation here that the wind will blow hard from the same point, and for a considerable length of time, over a large district. The study of observations taken at the same hour over an extensive tract of the earth's surface has, however, shown that the storms of the Temperate zone are without exception cyclonic, or partially so, in their character, although not so perfectly developed as those within the tropics. All cases of so-called straight-line storms are to be explained either by the persistence of the same characteristics for several days over the same region, or else simply by the fact that they are mere local phenomena, due to the contour of the country, like the exceptionally strong breezes often met with on rounding prominent bluff headlands, or, to use a more familiar illustration, at street corners. By this statement it is not meant to imply that strong winds from a definite point are not met with for days together in the region of the Trade Winds and Monsoons ; but, firstly, these forces seldom reach those of an actual 'strong gale,' and, secondly, the conditions which cause them are of the same nature as those which cause our own storms, and it is the persistence of the conditions which determines the constancy in the force of the wind.

In speaking of the general character of storms, it

should be mentioned that in most cases the vertical depth of the stratum of the atmosphere which is in the condition of storm is very small in comparison with the superficial extent of the area over which the storm is felt. Every one knows that it is a common occurrence to see clouds at a moderate elevation either moving rapidly while calm prevails below, or else at rest, or nearly so, while we are feeling a strong wind. On one occasion, August 18, 1875, when a whirlwind passed over a village in Sweden called Hallsberg, in the province of Nerike, it was expressly noticed that, while the branches of trees and fragments of the wreck of buildings were carried by the wind for miles, the clouds did not indicate the slightest sign of disturbance.

We have already spoken of great currents of air extending over vast tracts of the earth's surface, and the best idea which we can gain, for practical purposes, of the winds which affect us in these islands is that the air over the North Atlantic Ocean, north of Latitude 40° , is constantly flowing from west to east, like a gigantic river. If such a river be flowing rapidly, we often see on its surface small waves, each with its own eddies and circulations, which are carried on with the stream. If we could imagine it possible to look at the upper surface of the atmosphere, supposing it to be homogeneous and of equal density throughout, we should see much the same sort of conditions, except that what corresponds to the hollow of the wave would be a patch of defective pressure, while that which

corresponds to the crest of the wave would be an area of excessive pressure. We shall shortly learn how these areas influence the motion of the air and the weather.

There remains one general principle which was formerly brought forward as almost indisputable, and that is the principle known under the name of the 'Law of Gyration,' propounded by Professor Dove, of Berlin, some fifty years ago. This principle is, that the wind changes more frequently 'with the hands of a watch,' that is, from East, *through South*, to West, in the Northern hemisphere, than it does in the other direction, and that this is true all round the compass. The enunciation of this doctrine as an universal law has arisen from the fact of meteorology having been first studied in Western Europe, where the truth of the principle is undeniable. When, however, we look to the evidence cited by Professor Dove himself for Arctic stations, we find that the statements from those regions are not nearly so positive in favour of the law as the experience gained in lower latitudes, and the evidence from the German Arctic Expedition shows that on the east coast of Greenland the direction of change of wind was more frequently *against* watch hands than *with* them.

Moreover, when we come to consider the motion of wind in the systems of high and low pressure, of which we have just been speaking, and the motion of these systems themselves over the earth's surface, we shall

find that the question of the shifting of the wind in accordance with the law ('veering'), or its shifting in opposition to the law ('backing'), simply depends on the motion of the systems of circulation to which the winds in question belong. For instance, in the Northern hemisphere a wind 'veers,' or shifts, 'with watch hands' at any station when an area of low pressure passes from west to east to the northward of that station, and it 'backs' when the area of low pressure passes in the same direction to the southward of the station. See fig. 14 (p. 79).

The reason that veering, especially from SE. or S. through SW. to W. or NW., is so common in these islands is that the most usual path of cyclonic systems of air is from SW. to NE., the track of the centres of the storms passing to the northward of most stations in this country.

We have learnt, therefore, in this chapter, that wind is always connected with some disturbance of the pressure of the atmosphere, and it will be at once understood that its existence is due to the tendency of an elastic fluid, like the air, to regain the condition of equilibrium from which it has by any means been disturbed, while the motion of wind is regulated by certain fixed laws to which we have alluded, and which will be more fully stated presently.

CHAPTER III.

THE BAROMETER.

WE have next to consider what is the real nature of these disturbances of which we have been speaking. They are connected with irregularities in the distribution of atmospherical pressure. We only say 'connected with,' and do not say 'traceable to,' or use any more positive expression of opinion, for it is not proposed in this book to discuss the question of what the original causes of the disturbances are. Various theories have been propounded to account for storms, and some will be mentioned in Chapter VII., but none of them have met with general acceptance as yet. We must therefore only take things as we find them, and endeavour to make the best of them.

But it is necessary, at the outset, to explain the meaning of some of the terms which will recur most frequently in the following pages.

The first of these is the word 'isobar,' which is derived from two Greek words signifying 'equal weight.' *An isobar, or isobaric line, is a line passing through those places where the barometrical pressure is equal.*

If we look at the chart (fig. 1, p. 34) containing the readings from a report for a day, we see that the readings, all of which are shown on the chart, varied from 29.88 at Nice to 30.54 at Stockholm and Christiania. We find several lines drawn across the chart: all these lines are isobars, and the values of each are given.

The courses of these isobars are determined with reference to the stations on each side of them where actual observations exist, the probable position of the line in each case being ascertained by dividing the distances between the stations in proportion to the difference in readings between them. Similarly, points are found for isobars crossing the North Sea by dividing the distance between the stations on each side of that sea in proportion to the difference in readings between them. In this manner the courses of isobars drawn over the sea, and in regions whence no observations are obtainable, are inferred from the readings taken at the nearest stations whence observations have been received. As a general rule isobars drawn on comparatively insufficient information are dotted instead of being drawn in full.

The isobar of 30.5 forms a closed curve, passing through Stockholm and enclosing the southern part of Sweden as well as Christiania and the Scaw, that of 30.4 ins. starts from the Gulf of Bothnia, north of Hernösand, passes close to Skudesnaes (30.39), York (30.41), and Prawle Point (30.41), through Cape

Gris Nez (30.40), and is carried out over Northern Prussia.

The lines of 30.3 and 30.2 run across Norway and

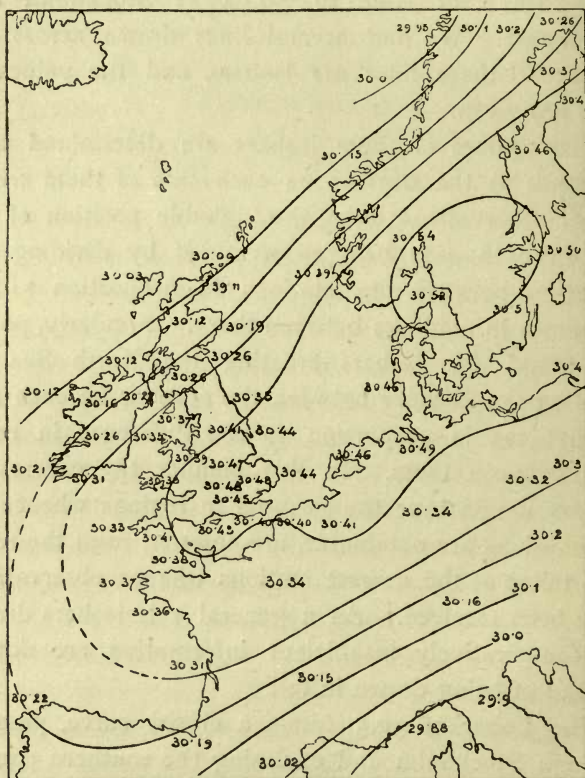


FIG. 1.—January 1, 1887; 8 A.M. Barometrical Readings and Isobars.

the North Sea, on a course nearly parallel to that of 30.4, which has just been described. That of 30.3 passes

very close to Roche's Point and Rochefort (both 30.31) and to Berlin (30.32). It is dotted across the Bay of Biscay from want of information, as also is that for 30.2 ins. This latter passes very close to Valencia, Corunna, and Biarritz (30.21, 30.22, and 30.19 respectively); the line for 30.1 just skirts the coast of Norway, passing thence between Sumburgh Head (30.09) and Wick (30.11), and outside the coast of Ireland, to reappear over Southern and Central France.

The reading of 29.95 at Bodö necessitates the drawing of a line for 30.0 ins. in the extreme north of the map, while that of 29.85 at Nice calls for two other lines, for 30.0 and 29.9 respectively, over that part of France.

From what has been said, it will be understood that, as these lines pass between stations where the observations show higher or lower pressures respectively than the values assigned to the isobars themselves, it is presumable that the reading at any other station exactly on any line would have precisely the value shown by the isobar.

These isobaric lines are drawn on all weather charts, and a knowledge of their respective values in barometrical readings, and of their courses, lies at the very foundation of all that we know about weather.

It will already have been seen from fig. 1 that the readings are not the same at all stations simultaneously, and, if we look at any chart representing the conditions of barometrical pressure over an extensive region for

any epoch of time, we shall find that this pressure is not equal at all stations, being greater in some places than in others. If we then proceed to draw the isobars, we shall find that several of these lines, like that for 30.5 ins. on fig. 1 (p. 34), form closed curves round certain spots where the barometrical readings are either *lower* or *higher* than they are over the neighbouring districts.

These two contrasting states of affairs are known by different names. The districts of low pressure, or of depression, are termed 'cyclonic,' and those of high pressure 'anticyclonic,' the names being derived from the Greek word *κυκλόω*, to whirl round in a circle, and conveying the fact that the wind in each class of area has a tendency to circulate round the centre of the system of disturbance, but in opposite directions in the two cases.

There is a very marked difference between the areas in which the barometer is lower, and those in which it is higher, respectively, than in the surrounding districts, for the temperature and the weather, as well as the circulation of the wind, differ most materially under the respective conditions.

In both cases there is a calm at the centre, or over the region enclosed by the innermost isobar, and, as a general rule, in cyclonic systems the extent of this calm centre is less, and the isobars surrounding it lie closer together, than in anticyclones. We shall shortly learn that this indicates a material difference as regards the force of the wind.

In order to illustrate this it will be necessary to give some charts as instances respectively of cyclonic and anticyclonic disturbances, which have existed over the region embraced by our telegraphic reporting system. It is, however, comparatively seldom that the whole of a system of either kind will be found developed over our limited district. More frequently we only find curves trending one way or the other, which enable us to conclude, from the general distribution of pressure, in what direction the central area of high or of low pressure, as the case may be, is situated.

Fig. 2 (p. 39) gives a good example of an area of low pressure, or a 'depression,' or a cyclonic disturbance, for the terms are used almost indiscriminately, developed as fully as it is usual to find them in Western Europe. Since the mode of drawing isobars has already been explained, it has not been thought necessary to reproduce the actual barometrical readings at the different stations.

It will be noticed that the chart contains other indications, besides those afforded by the isobars, which require some explanation.

The direction and force of the wind are given by arrows: a circle indicates a calm, as the wind has neither direction nor force.

The direction is shown by the direction in which the arrow is flying.

The force is indicated by differences in the symbols employed, which are as follows:—

38 *Weather Charts and Storm Warnings.*

Forces 0-1 (Beaufort scale, p. 8)	☉
„ 2-4	→
„ 5-7	→
„ 8-10	↗
„ above 10	↘

Thus it will be seen that there is a very heavy gale at Rochefort from WNW., a heavy gale at Scarborough from SE., a fresh breeze at Aberdeen from E., a light breeze at Brussels from SSE., and a calm at Toulon. (See Appendix A., p. 218.)

The lowest reading (28.55 inches) is at Holyhead ; the highest (30.00 inches) at Corunna.

The innermost isobar (28.6) embraces almost the whole of Wales. That for 28.8 is oval in shape, and covers nearly all England, and the east and north of Ireland. That for 29.0 takes in a little of France and Belgium, and the greater part of Scotland. The isobar of 29.2 envelops the whole of Scotland, but is not carried out over the Atlantic beyond the Orkneys on one side and the coast of Brittany on the other, and it is only dotted in, as being merely inferred, in the absence of observations, over the Bay of Biscay.

The other isobars are only partly shown ; in fact, the position of a portion of that for 30 inches is only indicated by the single observation of 30.00 at the station of Corunna.

The chief feature noticeable in the northern part of the chart is that the isobars of 29.4 and 29.6 trend away to the northward, and so the curves spread out in

a fan shape between the Shetlands and the coast of Norway.

If we now turn to the wind arrows, we shall find

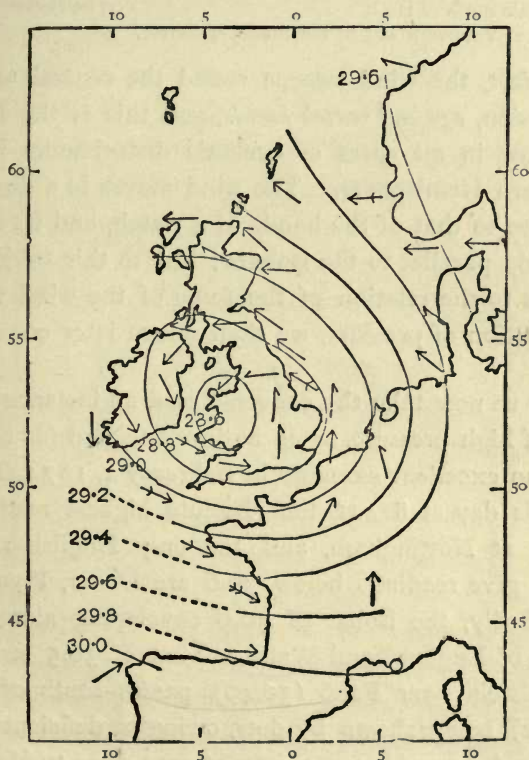


FIG. 2.—November 29, 1874; 8 A.M. Isobars and Wind, Cyclonic System.

that they show a circulation round the centre of depression. They are :

40 *Weather Charts and Storm Warnings.*

Westerly at Scilly and in France	. . .	on its southern side.
Northerly at Valencia	}	. . . on its western side.
North-north-east at Donaghadee		
East at Ardrossan	. . .	on its northern side.
South-east along the whole east coast of Great Britain north of Hull	}	on its eastern side.
South at Yarmouth and in the Straits of Dover		

In fact, the wind sweeps round the central area of depression, *against watch hands*, and this is the invariable law in all cases of cyclonic disturbances in the Northern Hemisphere. The wind moves in a direction opposite to that of the hands of a watch, and its course is nearly parallel to the isobars ; but to this subject, as well as to the relation of the force of the wind to the distribution of pressure, we shall return later on.

Let us now take the converse case, an instance of an area of high pressure, or an anticyclone, and for this we have an excellent example in February 4, 1874 (fig. 3). On this day at 8 A.M. the absolute highest reading is 30.67 at Nottingham, and the only English reports which give readings below 30.6 are Dover, Plymouth, and Scilly, the isobar of 30.6 enveloping almost the whole of England and Wales. That of 30.5 stretches to Holstein near Fanö (30.49), passes south of Paris (30.52), being shown by dots, owing to deficient information, between these points, sweeps close to Valencia (30.49), is again dotted over the sea outside the coast of Ireland, and finally reaches Aberdeen (30.49).

In the north and south readings decrease rapidly ; on the south side, the curve for 30.40 passes half-way

between Rochefort and Biarritz, and 30.30 skirts the coast of Spain and the Pyrenees, readings being 30.28 at Corunna, and 30.24 at Toulon. In the north 30.4

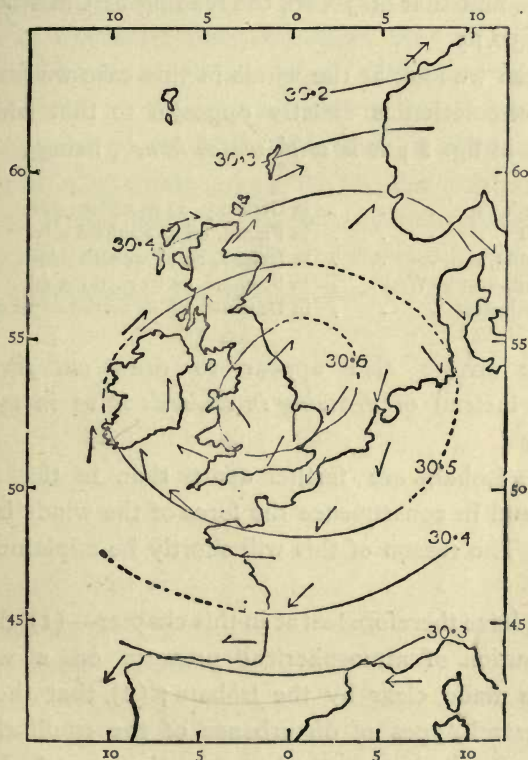


FIG. 3.—February 4, 1874; 8 A.M. Isobars and Wind, Anticyclonic System.

passes below Stornoway (30.39), runs between Wick and Thurso and across to Jutland, where the reading

at the Scaw is 30.34. Passing further north, 30.30 runs close to Sumburgh Head and across to the neighbourhood of Bergen in Norway, while above it still we find that of 30.20, the reading at Christiansund being 30.15.

When we look at the winds in this case we find that their circulation is exactly opposite to that which is shown in fig. 2 ; it is *with watch hands*, being :

North	in Germany, on its eastern side.
East	in France, on its southern side.
South	in Ireland, on its western side.
South-west to West	in Scotland, on its northern side.
North-west	in Denmark, on its north-eastern side.

The arrows also appear to draw *out from the centre* instead of *drawing in towards it* as in cyclonic systems.

The isobars are further apart than in the former case, and in consequence the force of the winds is much less. The reason of this will shortly be explained.

We have therefore learnt in this chapter—(1), that the distribution of atmospherical pressure on a weather map is made clear by the isobars ; (2), that there are two grand types of disturbance of the equilibrium of pressure, called respectively, *a*, cyclonic and, *b*, anti-cyclonic, according as the pressure in a given locality is either in defect or excess of its mean value over the surrounding region ; (3), that these two types are characterised by strong contrasts to each other, among

which the most striking are the differences in the direction of motion of the wind.

Cyclonic and anticyclonic are, however, merely *relative* terms ; the reading may be above 30 inches at the centre of a cyclonic area, and below 29.5 inches at the centre of an anticyclonic region. If at any place, or over any district, the barometrical reading is *lower* than at the places all round it, that place or district is the centre of a cyclonic area ; if, on the contrary, the reading at the place or district is *higher* than at the places all round it, that place or district is the centre of an anticyclonic area.

CHAPTER IV.

GRADIENTS.

LET us now proceed to examine still more closely into the principles in regard to the motion of the wind, which have only been faintly hinted at before. The direction of motion of the wind, in relation to the distribution of atmospherical pressure, may be easily perceived to be such that if you stand with your back to the wind the barometer will be lower on your left hand than on your right. This is the principle already cited, and generally known, as Buys Ballot's Law. It is simply the extension, to all cases of wind motion, of the Law of Storms first announced by Redfield and Reid for the Hurricanes of the West Indies as well as for the Typhoons of the China seas. The Hurricanes of the Southern Indian Ocean obey a similar law. The direction of rotation is opposite in the two hemispheres. The law as above stated refers to the Northern Hemisphere. The law therefore gives the *direction* of the wind, but it also enables us to judge of its *force*, for it is found that this latter depends mainly on the amount of difference of pressure between adjacent stations.

Air, being a gas, is even more mobile than water, and as the least difference in level between two portions of a free surface of the latter generates motion, tending to produce equality of level ; so in the former case the slightest difference of pressure causes motion in the atmosphere, in the endeavour to restore equilibrium of pressure.

It is evident that the greater the difference of pressure over a given distance, the greater will be the effort, and consequently the more violent and rapid will be the motion required to regain equilibrium. There is therefore a convenience in fixing a standard of comparison by which to measure the disturbance of pressure, and here meteorologists borrow an idea from engineers, who measure the inclination of a road or railroad by what is termed the 'gradient,' implying, when they speak of a gradient of one in sixty, that the slope rises one foot vertically for every sixty feet of horizontal measurement.

Meteorologists speak of gradients also, but, instead of applying the same unit of measurement, as of feet, to the vertical and horizontal scales, they give the vertical scale in units of barometrical measurement, and the horizontal scale in miles of distance. These gradients therefore are expressed in differences of barometrical pressure over a given distance. The first person to introduce the term gradient into meteorology was the late Mr. Thomas Stevenson, C.E.

The gradients adopted by the Meteorological Office

are expressed in hundredths of an inch of mercury per fifteen nautical miles.¹

In the accompanying figure (fig. 4), the horizontal distance between the two stations A and B is supposed to be fifteen nautical miles. The divisions on the vertical line B D are hundredths of an inch, and they correspond to the differences between the barometrical readings taken at the same hour at the two stations. The gradients are the ratios between the intercepts

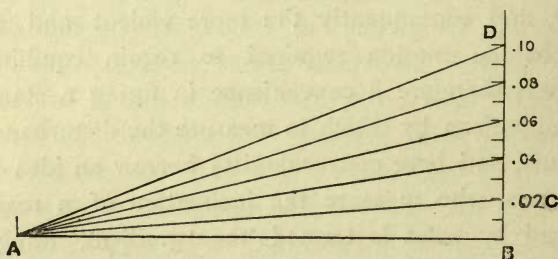


FIG. 4.—Gradients.

B C, B D, &c., and the line A B which is supposed to be = 1. The gradients are given as 2 for the angle B A C, $\frac{10}{8}$ for the angle B A D, corresponding to the several observed differences. These lines A C, A D, &c., are imagined to be drawn every morning between the most important stations given in the Daily Weather Report, and from their inclinations conclusions as to the probable direction and force of the wind for

¹ On the Continent gradients are measured as millimetres per one degree of sixty nautical miles. These gradients are therefore almost identical with ours, for one millimetre is nearly 0.04 inch.

the day are drawn. It is found, for instance, that the force of the wind will not exceed the figure 5 or 6, a 'fresh breeze' on Beaufort's scale, unless the gradient be higher than 2 (A C on the diagram).

To reduce this statement to a practical form, we may put it in these words. The distance from Penzance to Brest is 113 nautical miles. A gradient of 2 between these stations represents a total difference in barometrical readings of 0.15 inch, so that, in accordance with what has just been said, whenever a Westerly gale is blowing at the entrance of the Channel we may expect that the barometer at Penzance will be at least 0.15 inch lower than that at Brest; *vice versa*, the readings at Brest will be proportionably lower than those at Penzance whenever an Easterly gale is felt in the district in question.

An instance in point for the former state of affairs is the gale of January 8, 1870, during which the reading at Brest at 8 A.M. was 29.38, and that at Penzance at the same hour was 29.19. The difference between these readings is 0.19, and the resulting gradient 2.5. A very severe Westerly storm was that morning reported from the Channel.

The converse conditions accompanying an Easterly gale were observed on May 14, 1869, when the reading at Penzance was 29.92, and that at Brest 29.68. The resulting gradient is 3.2, and accordingly heavy Easterly gales were felt on our Channel coast.

To apply the same principle to the winds of the

British Islands generally, it may safely be asserted that no storm of any serious extent is ever felt over the United Kingdom unless there be an absolute difference in barometrical readings exceeding half an inch of mercury between two of our stations.¹

The difference in readings between Rochefort and Aberdeen on February 1, 1868, when a tremendous Westerly gale was raging, was as much as 1.76 inch, the reading at Rochefort being 30.16, and that at Aberdeen 28.40 inches. These figures give a gradient of 4 over the entire distance of 673 miles, and we find that gales were reported from seventeen stations that morning.

No very precise relation has as yet been established between the amount of the gradient and the force of the wind, but as a convenient figure to be remembered it may be repeated that a gradient of 0.02 inch per 15 miles indicates the probability of as much wind as an ordinary yachtsman likes to meet with.

We are now in a position to see more clearly how entirely this idea of gradients does away with the old notion that the actual height of the barometer at one station gives a certain indication of the probable direction or force of the wind or of the character of the weather at that station, a notion which has found expression in the words 'Very Dry,' 'Fair,' 'Change,'

¹ Local storms, which occasionally do great damage, may be felt when the barometrical disturbance is itself only local, and when the actual amount of difference between the extreme readings is less than half an inch, although the gradients for a short distance may be high.

'Rain,' 'Stormy,' &c. &c., which have been for so many years placed on barometer scales.

The small trace of truth which the scale lettering in question contains is accounted for in the following way. On the average of a great many readings of the barometer, taken under various circumstances as regards the direction of the wind, it is found that in these islands the reading is highest when the wind is North-easterly, and, as has already been stated, this is when the air is coldest and driest. Consequently we have 'Very Dry' put down at the top of the scale, and according as the mercurial level rises from 'Change,' 29.5 inches, to its maximum height, we have 'Fair' or 'Set Fair' entered. Conversely, when the air is warm and moist and the wind South-westerly, the barometer is low, and so we have then the descending scale of 'Rain,' 'Much Rain,' and 'Stormy.' It is, however, quite a mistake to imagine that on any given day there is any certainty of the weather according with the description of it given by the word corresponding to the barometer height for that day.

There are yet other points of view from which the inutility, and in fact the absolute error, of these words may be indicated.

Let us take for example the word 'Change;' this is placed opposite the reading 29.5 inches, which reading is naturally supposed to be taken at sea-level. If the barometer be removed to a station situated, say, 500 feet above that level, the corresponding reading

will be about 29 inches, so that the whole scale will be half an inch out, and the error will be the greater the more considerable is the height of the station. The lettering is therefore wrong for another reason, because it does not take account of the necessary reduction of the reading to sea-level.

Once more, the range of the barometer is far greater in winter than in summer, so that the reading which corresponds to 'Fair' should be much nearer to 'Change' in summer than in winter. The lettering is therefore still further in fault, as taking no account of this difference. The words are in fact little less than utter nonsense.

It is undeniable that there is more chance of strong wind when the barometer is low than when it is high, but this arises, not from the actual height of the barometer, but from the circumstance that cyclonic areas are usually much smaller than anticyclonic, so that when the barometer is low there is a greater probability of a steep gradient, from adjacent higher readings, existing in the neighbourhood, and causing high winds, than is the case when the barometer is high.

It, however, sometimes happens that the barometer in these islands will remain for a day or two below 29 inches, that is, below 'Stormy,' without any gale, because the area of low pressure is extensive and the gradients slight. An instance of these conditions has already been cited at p. 27 as having occurred March 9, 1876.

The question is often asked why gradients can be said *to be for certain winds*? The answer to this is very simple. Let us recur to fig. 2 (p. 39), and add to the curves and arrows already shown a number of

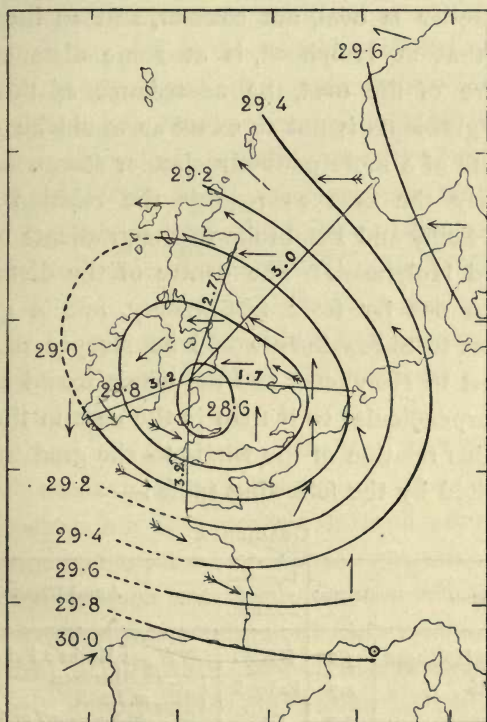


FIG. 5.—November 29, 1874; 8 A.M. Isobars and wind, with principal gradients.

straight lines joining Holyhead to Valencia, Aberdeen, Skudesnaes, the Helder, and Brest. These lines (fig. 5) represent the direction of the gradients, and a glance

at the chart will show that the winds, as regards their direction and force, bear a definite relation to these gradients in accordance with Buys Ballot's Law.

It will, however, be seen that as the form of the central isobar is oval, not circular, and as the lowest reading, that at Holyhead, is at some distance from the centre of the oval, the accordance of the winds with the gradients is not so exact as would be evinced in the case of a more perfectly circular storm. This is particularly the case as regards the relation of the winds at Scilly and Pembroke to the gradients between Brest and Holyhead. The centre of the disturbance really lies not far from Shrewsbury, and a gradient from Brest to Shrewsbury would be steeper than that from Brest to Holyhead, and the winds would be more nearly perpendicular to it than is the case in the chart. In fact, this relation of the winds to the gradients may be exhibited by the following table:—

GRADIENTS.

Stations.	Amount	Direction of Wind indicated.	Actual Winds.
Valencia to Holyhead	3.2	NNW.	NW ₈ at Roche's Point
Aberdeen to „	2.7	E. by S.	{ E ₇ at Aberdeen
Skudesnaes to „	3.0	ESE.	{ SE ₇ at Leith
The Helder to „	1.7	S.	{ SE ₁₀ at Scarboro' and Shields
			{ S ₅ at Yarmouth
			{ S ₇ at Cape Gris Nez
Brest to „	3.2	W.	{ WNW ₁₀ at Scilly
			{ W ₉ at Brest

It is needless to multiply examples. The chart shows a complete cyclonic circulation, and the gradients

are taken on various sides of the centre. The entire condition furnishes a clear ocular proof of the statement that the wind is nearly perpendicular to the gradients, and therefore nearly parallel to the isobars.

From the way in which the direction of the gradient is described, we gather the direction of the wind indicated. When we speak of a gradient from Valencia to Holyhead being for North-westerly winds, we imply that the reading at Valencia is the higher of the two readings, *the station with the higher reading being always placed first*, and so a man standing midway between the two stations, with the lower barometer on his left-hand side, would face SSE. and have his back to the NNW.; the wind would therefore be North-North-westerly, which brings us back again to Buys Ballot's Law.

We have now learnt how the idea that the reading of the barometer at any time gives an indication of probable weather is controverted by the more correct conception of the value of gradients, but there is another idea which, though not absolutely misleading, is yet an unsafe mode of interpretation of barometrical readings. This is the idea that the motion of the mercury in the barometer is an infallible indication of coming weather. It is often asserted that if the barometer falls, say, at the rate of one-tenth of an inch per hour, a storm is certain to ensue at the place.

Depressions with slight gradients, moving quickly, will, however, cause the barometer to fall, at stations

over which they pass, as rapidly as depressions with steep gradients which move slowly.

It is of course true that if an area of depression passes over us the barometer will fall till the centre has gone by, and then will rise, and that the rates of such fall and rise, for a given rate of motion, will bear a close relation to the amounts of the gradients along the path of the centre; but it is not by any means certain that because a barometer falls rapidly there must be a gale at the place where this fall is observed. A very telling instance of the fallacy of this opinion is to be found in the following case, when the barometer fell with extraordinary rapidity over an extensive region, and yet hardly at a single station within that region was there any gale felt.

November 22, 1869, a very remarkable barometrical depression was manifested over Western Europe. The actual fall of the mercury, since 8 A.M. on the 21st, had exceeded 0.9 inch over the entire district extending from Dover to Valencia and from Lorient to Shields. This area is bounded by the meridians of 1° E. and 11° W. and by the parallels of 48° and 55° N., and its superficial extent is about 200,000 nautical square miles.

On this occasion, although there was such an enormous disturbance of equilibrium, there were absolutely no strong winds reported on our coasts during the day, excepting slight gales from North-west at Cape Clear and from South-east at Yarmouth.

Outside our west coasts, however, on the edge of the disturbance, gradients were very steep, and there gales were felt between the 21st and 23rd, not only by the Atlantic steamers *Scotia* and *City of Brooklyn*, which were near the Irish coast, but also by the *Inverness* and *Foam*, which were further south. In fact, the last-named vessel, in the latitude of Cape Finisterre, was driven to the southward, out of her course, and suffered severely. At Corunna, however, and on the coast of Portugal, the gale was not felt seriously at all. In this case, therefore, a fall of the barometer of an inch at several stations was not followed by a gale *at those stations*.

March 9, 1876, the instance already quoted (p. 27), affords quite as striking an illustration. That morning, at 8 A.M., the fall in the barometer within twenty-four hours had amounted to 1.1 inch at Wick, had exceeded an inch over the entire north and east of Scotland, and had been more than 0.8 inch over the rest of Great Britain, most of Ireland, and the north of France, yet the only wind of a force above 7, 'a moderate gale,' was at Rochefort, where a heavy Westerly gale was reported, and near the very centre of the disturbance, *where the barometrical fall was the greatest*, the force of the wind was the slightest, because the gradients were least.

This entire depression, like that mentioned just above, passed off without causing any gale worth notice in the United Kingdom.

We have learnt in this chapter that the distribution of pressure, as defined by the gradient, is the best guide, by the use of the barometer alone, towards a knowledge of the laws of wind motion and, as we shall subsequently learn, of coming weather ; but it must be stated that it appears that the force of the wind is not regulated *solely* by the gradients, though meteorologists have not yet determined what are the other agencies which influence it.

It is therefore evident that any attempt to foretell weather by the indications of the barometer at any one station, unsupported by observations of wind, clouds, weather, &c., must necessarily be imperfect. The direction and force of the wind in no way depend on the actual barometer reading at the time.

We have, moreover, seen the meaning of the phrase 'gradients for such and such winds,' which are nothing more than the expression in a practical form of the laws of wind motion.

CHAPTER V.

CYCLONES AND ANTICYCLONES.

THE consideration of gradients, and of the effects of the distribution of pressure, brings us to contrast the two classes of atmospheric systems, anticyclonic and cyclonic, and the weather they bring with them.

Anticyclonic systems are marked by a very slow circulation of the air, or, in other words, by light winds, by low temperature in winter, great dryness of the air, at least at the centre, and consequent absence of rain, although fog is frequently very prevalent. These circumstances are accounted for by the fact that the air, in an anticyclone, flows out from the centre, and therefore must be supplied from the upper regions of the atmosphere by a descending current, which cannot possibly contain much moisture, owing to the very low temperature of the regions from whence it is drawn, and which is actually rendered drier by the fact of its descent.¹

¹ Air ascending is expanded, it falls in temperature in the process, and the moisture it contains is consequently liable to be condensed and to form clouds, and ultimately fall as rain. Conversely, air descending is compressed, it rises in temperature in the process, and consequently its capacity for containing moisture is increased, and it feels dry.

Cyclonic systems, on the contrary, are distinguished by the exact converse of the above conditions. The air circulates more rapidly, causing strong winds, and flows in towards the centre, so that it must naturally be supplied from below and ascend in the centre. Cyclones in these latitudes bring with them, at least over a considerable proportion of the area they cover, a comparatively high temperature, much moisture, and consequently heavy rain. We say, over a considerable proportion of the circumference, because, in certain parts of a cyclonic system, the wind which is felt is often very dry. This is in the rear of the disturbance. In the Tropics, there is not such a contrast between the different parts of a cyclone, as regards dryness.

These statements refer to the winter ; in summer the conditions are exactly reversed, at least as regards the temperature which accompanies the respective systems of disturbance.

Anticyclonic systems in summer, produce our hottest weather, inasmuch as the air is so dry that no heavy clouds can be formed, so that the sun has full opportunity for exerting his heating power, while there is hardly any motion in the air to produce a cooling breeze.

Cyclonic systems in summer, on the contrary, bring cloudy weather, rain, and a reduction of temperature, the latter being mainly due to the density of the cloud covering which intercepts the direct rays of the sun.

It is easy to illustrate these statements by examples.

Let us take the instance of an anticyclone first, in fact the very day which we have already cited, February 4,

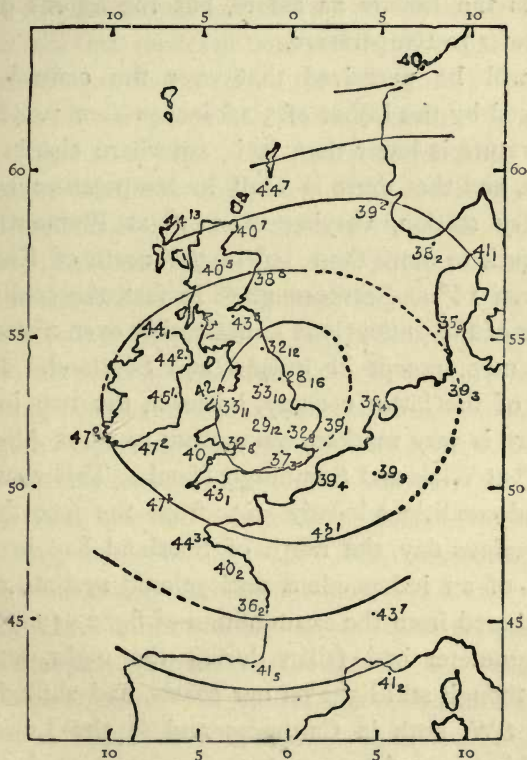


FIG. 6.—February 4, 1874; 8 A.M. Isobars and temperature, showing changes in previous twenty-four hours.¹ Anticyclone.

¹ The changes of temperature in figs. 6 and 7 are shown by small figures placed after the thermometrical readings. When these figures are *above* the readings, as at Wick (in fig. 6), they indicate a *rise* of temperature; when they are *below*, as at Scarborough, they indicate a *fall*.

1874 (fig. 3, p. 41), which will serve as a very good illustration of a winter anticyclone. Fig. 6 (p. 59) exhibits the isobars as before, but the figures on the chart refer to temperature.

It will be perceived that over the central area, embraced by the isobar of 30.6 inches (see p. 41), the temperature is lower than it is anywhere else in these islands, and that there is a fall in temperature noticed at every station, varying from 1° at Plymouth and Yarmouth to more than 10° in the north of England, and even 16° at Scarborough. In fact, the cooling influence of the anticyclone is noticeable over almost the whole map, except in Ireland and Scotland. In the north of the latter country, however, the rise in temperature is very marked, amounting to 8° at Aberdeen and 7° at Wick and Sumburgh Head. This change of thermal conditions locally arose from the fact that, on the previous day, the north of Scotland had been the region of an independent anticyclonic system, as will be gathered from the examination of fig. 24 (p. 93), but the barometer had fallen during the night, and the wind, though still light on our coasts, had shifted from N. to SW. both in Caithness and in the Lews. In fact, this rise of temperature was connected with a cyclonic disturbance further northward, which is shown in fig. 26 (p. 94).

As regards the force of the winds, a glance at fig. 3 (p. 41) is sufficient to show that they are very light ; in fact, the only British or Irish station where they exceed

the force of 5 of the Beaufort scale, a 'fresh breeze,' is Scilly.

The general dryness of the air is sufficiently evinced by the fact that rain was not recorded for this morning from more than five stations out of the fifty-one mentioned in the Reports, at three of them the amount being only 0.01 inch ; the greatest quantity was at Scilly, and that was only 0.06 inch ; nevertheless, the actual difference between the dry and wet bulbs was but slight, showing that the atmosphere was near its point of saturation for the temperature. This circumstance is partly owing to the fact that the observations were taken at 8 A.M., so that the influence of the sun's heat had hardly made itself felt. In fact, what moisture there was, was present in the form of cloud or fog. The reader may be interested to learn that owing to this latter condition the only region where the sky was clear was the north of Scotland, and that a traveller coming south would have met with an entirely overcast sky at Leith, while fog and mist were reported all along the east coast of England, as being either prevalent at 8 A.M. or as having been so during the preceding twenty-four hours.

Frequently, though this was not the case in this particular instance, these fogs only last during the early part of the day and clear off about noon, as the diurnal range of temperature during the existence of anticyclones is often very great.

These conditions are more or less characteristic of

the entire class of areas of high pressure, and, as we shall shortly proceed to show, the most striking feature of the weather which accompanies them is its permanency, *i.e.*, the slowness with which changes succeed each other.

Let us now take the case of a cyclonic area (November 29, 1874), fig. 2, the very instance which has been already cited (p. 39), and examine into the features which characterised the weather which this system brought with it. This storm was so typical that the Weather Report and Charts for the day have been reproduced in Appendix A. (p. 218).

In the first instance we see (fig. 7) that over almost the whole of the map the rise of temperature from the previous day (indicated by figures *above* the readings, as before) has been very striking, especially at the south-eastern stations, where the increase has exceeded 10° , amounting even to 23° at Cape Gris Nez, near Boulogne. This region lies in front of the advancing disturbance, and is the district of the Southerly and South-east winds. The motion of this particular storm will be traced subsequently (figs. 19–22, pp. 90–92).

In the rear of the storm, *i.e.*, in Ireland and Cornwall, where the wind has shifted to North-west, we find that a fall (indicated by figures *below* the readings) is reported at all the Irish stations, as well as at those in the extreme north of Scotland. That this is due to the direction of the wind is sufficiently clear from the fact that, at almost all the places where the cooling effect is

observable, the direction of the wind is from some point to the Northward of West, being NE. at Donaghadee, N. at Valencia, NW. at Roche's Point, and WNW. in

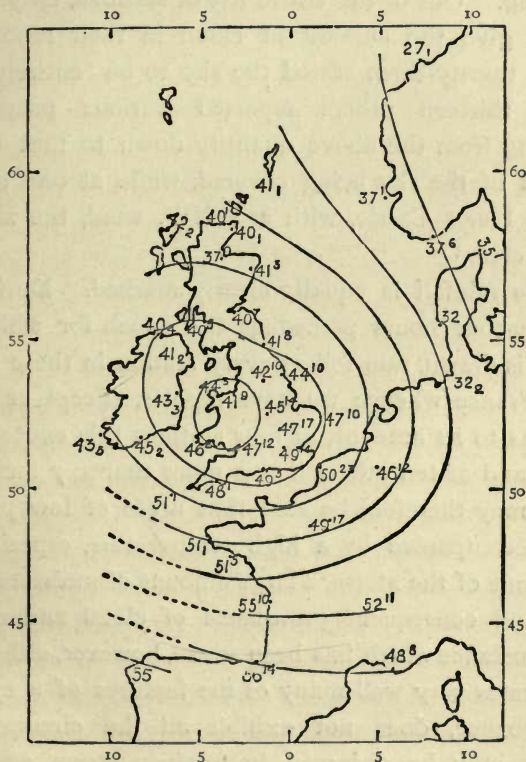


FIG. 7.—November 29, 1874; 8 A.M. Isobars and temperature, showing changes in previous twenty-four hours. Cyclone.

the south of England, where, although no fall of temperature from the reading at 8 A.M. on the previous day

is reported, the rise at Scilly and Plymouth is only 1° , as compared with 10° at Dover and 14° in London.

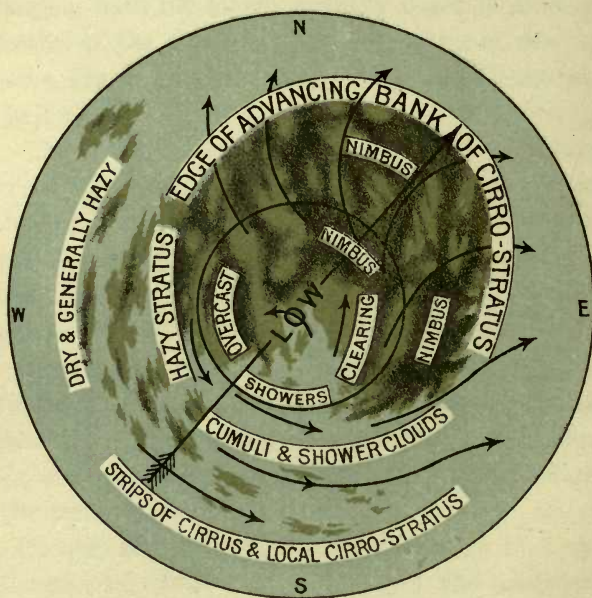
As regards clouds and rain, the facts are still more striking. Out of the entire list of stations, only thirty-seven give the amount of cloud in their reports: of these, twenty-three stated the sky to be 'entirely over-cast,' thirteen others reported various proportions ranging from the above quantity down to that of six-tenths of the sky being covered, while at one solitary place, Hurst Castle, with a WNW. wind, the sky was 'half clear.'

The rainfall is equally clearly marked. During the twenty-four hours preceding the epoch for which the chart is drawn, rain fell at every station in these islands and France whence we have reports, except at Nairn, and, as to its amount, at four stations this exceeded an inch, and at ten others it was more than 0.7 inch.

It may therefore be said that areas of low pressure are accompanied by a high temperature, especially in the front of the storm, a large amount of moisture in the air, and consequent prevalence of cloud and rainfall. The instance which has been given, however, although it illustrates very well many of the features of a cyclonic disturbance, does not exhibit all the circumstances which may be observed in a given storm, as to the march of the different phenomena within the system itself.

As regards the distribution of clouds and weather in such a system, the Rev. W. Clement Ley exhibited, at

DISTRIBUTION OF CLOUDS AND WEATHER IN A
TYPICAL CYCLONIC DISTURBANCE
According to the Rev.W.Clement Ley.



a lecture which he delivered before the Meteorological Society in 1878, a diagram of which Plate II. is a reproduction ; the original appears in 'Modern Meteorology' (London : Stanford, 1879.)

In this the long arrow represents the direction in which the system is advancing, and the curved arrows indicate the motion of the wind. It will be seen that the cloud gradually becomes denser as the centre approaches a station, and that as the centre passes there is, on the right-hand side of its track, a sudden clearing up, the clouds, with the NW. wind in the rear of the system, being broken and giving rise to showers, not to continued rain.

On the left-hand side of its track there is no such sudden clearing up, as the cloud remains dense until the vane shifts beyond North, and the subsequent clearing is gradual.

One of the most striking characteristics of a cyclonic storm is the sudden shift of wind which takes place between SW. and NW., accompanied frequently by a heavy squall and a shower, together with an almost instantaneous fall of temperature, and this is entirely absent in the case of the storm shown on fig. 7, as will be explained on p. 92. To take a very remarkable instance of this squall, we find that on February 12, 1869, a cyclonic storm passed up the English Channel ; the lowest barometrical reading being recorded at Falmouth at noon, when the wind flew from SW. to WNW., and the temperature fell $6^{\circ}.2$ in a few minutes.

At Kew similar changes took place at 4.30 P.M., but in a very aggravated form : the shift of wind having been from WSW. to ENE., and the fall of the thermometer $11^{\circ}.6$ in about five minutes.

The storm of Sunday, March 12, 1876, was very severe in the south of England. In this, the shift of wind at Kew was from SW. to N., and the fall of temperature $8^{\circ}.5$ in thirty minutes, accompanied by a heavy snow shower. It is also a remarkable fact that, at the moment of this sudden change of temperature, the condition of atmospheric electricity changed from negative to positive. Further researches on this subject are very desirable.

I have already said that one great distinction between cyclones and anticyclones, is that the former move, and the latter are usually nearly stationary, and as the usual motion of a cyclonic system is from west to east across these islands, it will be interesting to see what we can learn, from the continuous records at our self-recording observatories, of the actual changes which will occur at a station during the passage of a storm moving in that direction.

This will naturally differ according as the station lies to the north or the south of the centre of the storm, and, as it very rarely happens that the storms are truly circular, it is obvious that the shifts of wind and changes of weather will not always be perfectly regular. In fact, the extraordinary changes of February 12, 1869, just cited, afford a very good proof of the

unequal distribution of the gradients in such a system of disturbance.

Let us first take the most common case in these islands, that of a station lying on the southern side of the path of the centre of a depression which is moving from west to east across central England, and that we are situated in London. We shall experience first the phenomena belonging to the front of the system: the appearance of cirrus clouds, 'mare's tails,' in the sky, then the South-easterly winds, the great rise of the thermometer and excessive dampness, the sky becoming gradually overcast and the setting in of mist and rain, the barometer falling persistently, while scud begins to drift from the Southward. As the system advances the barometer continues to fall, the wind veering through S. to SW., and rain falling steadily. As soon as the wind passes the SW. point and draws to W. or NW., the barometer begins to rise, often with a sudden jump, and the temperature falls, with a very heavy shower of rain, possibly turning to hail with a thunderstorm, after which the air becomes much drier, and the sky clears with a NW. wind, which as a rule soon dies down. After such a disturbance as this we have frequently a smart frost at night, inasmuch as the great dryness of the air has allowed of great radiation of heat from the ground.

It is not easy to find an instance which exhibits the entire course of changes just described, but the table, Appendix B. (p. 221), will illustrate several of the points.

The table represents the hourly readings of the barometer, thermometer (dry and wet), anemometer

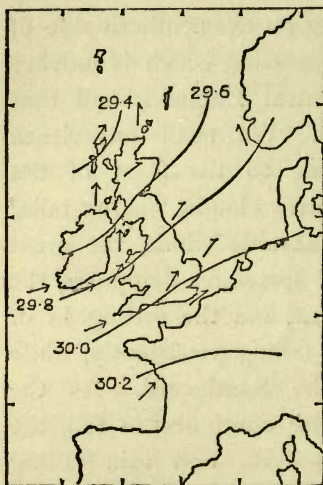


FIG. 8.—March 27, 1874; 2 P.M.
Storm passing north of Valencia.

(direction and velocity), rain-gauge, and the vapour tension from the continuous records at Valencia on March 26 and 27, 1874, when the centre of a cyclonic storm passed to the northward of that observatory. At 2 P.M., March 27 (fig. 8), the centre of the storm lay off the north-west coast of Scotland, outside the Hebrides. The diagram (fig. 9) exhibits the course of the curves.¹

The barometer fell steadily for twenty-three hours, until 9 A.M. on the 27th, and then rose in twelve hours nearly to the same height as it had held before. Tem-

¹ These diagrams require explanation. They are copied from the plates in the Quarterly Weather Report, and exhibit the continuous records of:

1. The barogram or barometer curve, marked *bar.* The scale for this is given in the lower left-hand corner. It is in inches, and the readings, though corrected for temperature, are not reduced to sea-level, and range over $1\frac{1}{2}$ inch.

2. The thermograms, marked respectively *dry* and *wet.* The scale for these is in the lower right-hand corner, and ranges over 30° .

3. The curve of tension of vapour, marked *vap. ten.*, calculated from the two thermograms, dry and wet.

4. The rain in hourly amounts of fall. These are measured upwards from the base line of the scale which serves for vapour tension and rain,

perature and vapour tension remained singularly steady during the afternoon of the 26th, rising very slowly during the night, and reaching a maximum at 8 A.M. nearly simultaneously with the epoch of the lowest

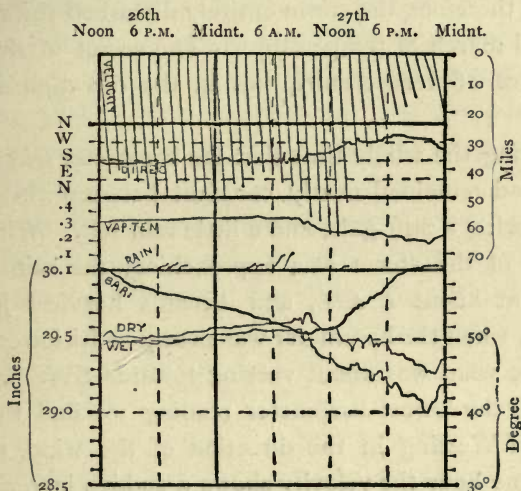


FIG. 9.—March 26 and 27, 1874. Automatic records at Valencia.

barometer readings. The thermometers then began to fall briskly, and by 9 P.M. the dry bulb had sunk $5^{\circ}.7$. It will be observed that, owing to the influence of the

and is on the left-hand side, above the barometer scale; it is in tenths of an inch, and extends over half an inch.

5. The wind direction, marked *direc.* This is on a special scale shown at the left-hand side, which represents a paper wrapped round a cylinder, and then laid flat. N is at the top, then come successively W, S, E, and N again.

6. The wind velocity, marked *velocity*, in hourly amounts, measured by the scale of miles, up to seventy, shown on the right-hand side.

The time scale is shown at top and bottom.

storm, the temperature was higher during the early morning hours of the 27th than it was during the afternoon of either the 26th or 27th, and yet 2 P.M. is usually about the warmest part of the day. While it lasted, therefore, the storm entirely disturbed the regular diurnal march of temperature. The secret of this disturbance of temperature lies in the direction of the wind.

During the whole time that the barometer was falling the wind remained nearly constant between SSE. and S., blowing a stiff gale, and a little rain fell. When the centre of the storm was approaching, the rain set in again at about 4 A.M., and became heaviest just at 8 A.M., when the barometer was nearly at its lowest level and the wind was about veering towards SW. At the hour of the lowest barometer reading we find the first trace of Westing in the direction of the wind, and at the same hour the velocity shows a sudden increase, the rain still continuing. The sky then cleared, the barometer rose briskly, and the wind increased till noon, when it blew a heavy gale from SW.byS. It subsequently veered pretty quickly to WNW. with a slight shower of rain at 3 P.M., and fell very light afterwards at 7 P.M.

The courses of the wet bulb thermometer curve, and of the curve of vapour tension, illustrate very clearly the contrast between the Southerly and North-westerly winds as regards the humidity of the air. As long as the wind remained to the Eastward of South the curves

of the two thermometers remained close to each other, and the vapour tension trace rose steadily, but very slowly. At the hour of the minimum barometer reading, we notice the thermometer curves going apart, and for the remainder of the period they pursued courses diverging more and more from each other, indicating, what is also shown by the descent of the vapour tension trace, that the air was becoming drier and drier according as the wind became more and more Northerly.

Owing to this extreme dryness of the air of the North-west wind, in the rear of a storm, it is believed by some meteorologists that this wind is a downrush of air from the upper regions of the atmosphere, which is necessarily very dry, as explained at the beginning of the chapter.

The case just cited, though it exhibits some of the phenomena with great distinctness, is not one which can be made clear to the reader as an instance of a storm passing to the northward of a station, inasmuch as the system to which the gale belonged was so extensive that the limited area of our charts would not exhibit the conditions in a convincing manner. Fig. 10 (p. 72), however, is an indisputable case of a storm passing on the northern side of Aberdeen, and close to it, October 20-21, 1874, and the course of the curves at that observatory is shown on fig. 11 (p. 73). The actual hourly readings will be found in Appendix C. (p. 222).

The fall of the barometer was slow at first, but then

increased in rapidity, and in twelve hours the mercury sank to the extent of 1.14 inch. It then rose in the next twelve hours as much as 0.8 inch, and for a portion of the time the rate of rise was more rapid than that of the previous fall had been. It will be noticed that the epoch of the maximum rise of the barometer was also that of the shift of wind through three points to the

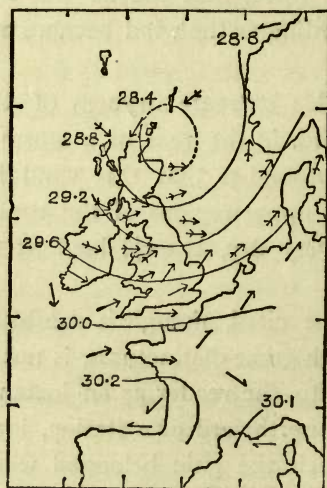


FIG. 10.—October 21, 1874; 8 A.M. Storm passing north of Aberdeen.

Northward, as well as of the strongest wind and the heaviest rain. This is the heavy shower of rain, coincident with the shift of wind to the North-west, of which mention has previously been made, p. 65. Temperature (dry and wet bulb) and humidity do not follow a similar course respectively as they did in fig. 9, as all

the curves are far less steady in their course than on the former occasion. We see, however, that the diurnal march of temperature is again entirely disarranged, the thermometers remaining pretty nearly at the same temperature throughout the night of the 20th, and the sudden fall of both temperature and vapour tension taking place nearly simultaneously with the shift of

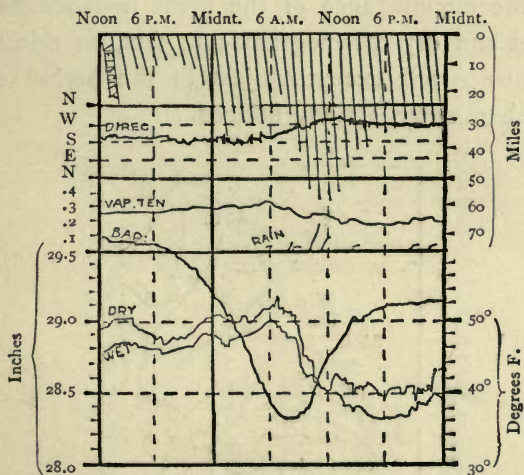


FIG. 11.—October 20 and 21, 1874. Automatic records at Aberdeen.

wind above noticed, and at the time when the natural rise of day temperature ought to be briskest, viz., about 10 or 11 A.M.

The wind commenced at about SSW., and blew pretty steadily from that quarter for twenty hours, its velocity being at first slight, and increasing to that of a stiff breeze at midnight. When the barometer was at

its lowest and beginning to rise, the direction of the wind rapidly shifted to WNW., and in three hours its velocity more than doubled itself, rising from 24 to 55 miles an hour. The velocity of a strong gale, however, only lasted for four hours, from 9 A.M. to 1 P.M. The absence of rain is very noticeable during the early period of the gale; the reason for this absence can be seen from the circumstance of the great distance between the wet and dry thermograms; in fact, no rain of any consequence fell excepting just at the period of the lowest barometer, already noticed.

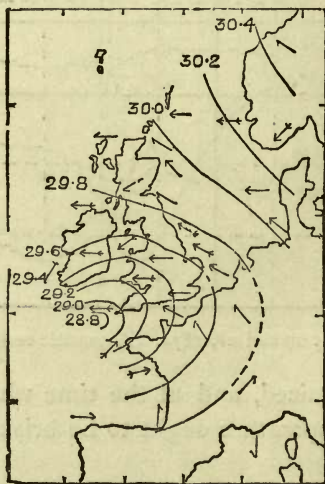


FIG. 12.—February 2, 1873; 8 A.M. Storm passing south of Falmouth.

It will be seen from figs. 51 and 52 (p. 157) that this storm, which was a very severe one in other parts

of the country, passed just to the northward of Aberdeen.

Taking now the second case, that of a cyclonic system passing on the southern side of a station, we have a very good instance of the course of the phenomena in the records of Falmouth for February 1 and 2, 1873. The hourly values, as before, are given in

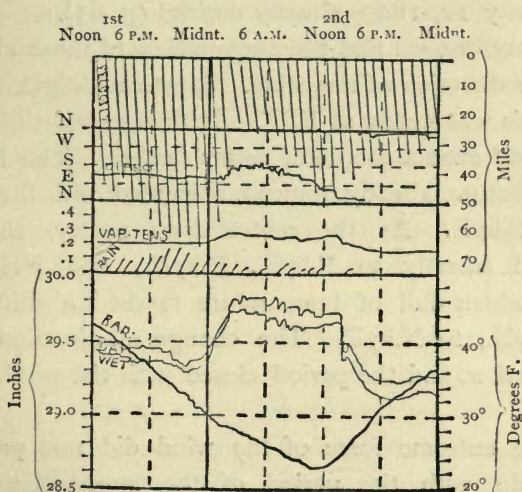


FIG. 13.—February 1 and 2, 1873. Automatic records at Falmouth.

Appendix D. (p. 223); and the instrumental records are shown on fig. 13, while the conditions of pressure at 8 A.M. on the 2nd are shown on fig. 12.

Here, too, as in the previous case, we have a great dip in the barometrical curve, which falls very regularly for twenty-four hours until noon on the 2nd. It then rises more rapidly than it had fallen before, and at

midnight on the 2nd attains to within a quarter of an inch of its previous height.

Temperature shows very remarkable changes during the night of the 1st and 2nd, rising 10° between 10 P.M. and 4 A.M. It then continues high until 2 P.M. on the 2nd, when it falls 6° in a few minutes, a change nearly as sudden as that at the same observatory on February 12, 1869, already noticed (p. 65).

As before, we find the explanation of these changes in the direction of the wind. Up to midnight on the 1st this was steady at ESE. It then veered slightly to SE., and even a couple of points further. The highest temperature, already noticed, coincided with the direction S.byE. As the centre drew nearer, the vane shifted smartly to E.byS., E.byN., and NE., and the sudden fall of temperature marked a shift from NE.byN., to N.byE. The change of direction went on further, and the period closed with the wind about NNW.

The extreme force of the wind did not precisely coincide with the period of the lowest barometer reading, as it was far greater a little before midnight on the 1st than at any other time. This affords a further proof, if such is needed, that the violence of a gale does not depend on the actual height of the barometer at the time.

Vapour tension shows a steady curve, following that of temperature, until the appearance of the Northerly and North-westerly winds, when it sank in a marked

way, thus again corroborating our former statement as to the dryness of winds from that quarter.

The rainfall was very remarkable; it continued almost without intermission from noon on the 1st till 5 P.M. on the 2nd, being heaviest shortly before the period of the strongest wind. The total amount which was collected during the twenty-four hours, ending with noon February 2, was no less than 1.275 inch, and it will be noticed that the rain gradually lessened as the wind shifted through N., and ceased entirely when the direction was NNW.

This persistence of rain with the Easterly and North-east winds in the front of a cyclonic depression is a very striking characteristic of these disturbances. It is an unmistakable proof that North-east winds are not always dry, and the only reason that this fact is not more frequently observed is, as will shortly be shown, that the occurrence of these winds in the front of cyclonic disturbances is a comparatively rare phenomenon in the British Isles, for the storms usually pass by us on the northern side, and at first give us South-easterly, not North-easterly winds.

These instances are amply sufficient to show the way in which we are to interpret a couplet, well known to sailors, which expresses Dove's Law of Gyration, referred to at p. 30 :

When the wind shifts against the sun,
Trust it not, for back it will run.

Under certain conditions a shift of the wind against

watch hands is quite *en règle*, and is simply an indication that a cyclonic disturbance is passing on the southern side of the observer. The actual motion of the disturbance of February 1 and 2, 1873, was along the north coast of Brittany, and therefore to the south of Falmouth.

The rule as regards the shifting of the wind in connection with atmospherical disturbances may be thus stated.

If the observer supposes himself at the centre of a cyclonic system in the Northern Hemisphere and facing in the direction in which it is advancing, the wind at all stations which he passes will *shift with watch hands* if the station be on his *right-hand side*, and will *shift against watch hands* if the station be on his *left-hand side*.

This is made clear by the following diagrams (fig. 15, *a, b, c, d*), in which I. II. III. indicate the successive positions of a cyclonic system, and the large arrows represent different directions of its motion. A is always on the right-hand side of the centre, B on its left-hand side. The successive directions of wind experienced at each station are shown by the figures 1, 2, 3, and 1', 2', 3'. In every case it will be seen that the shift from 1 to 3 is *with watch hands*, and from 1' to 3' is *against watch hands*, whatever the first direction of the wind may have been.

The reason that a shift of wind against watch hands is considered dangerous is, that when the wind shifts

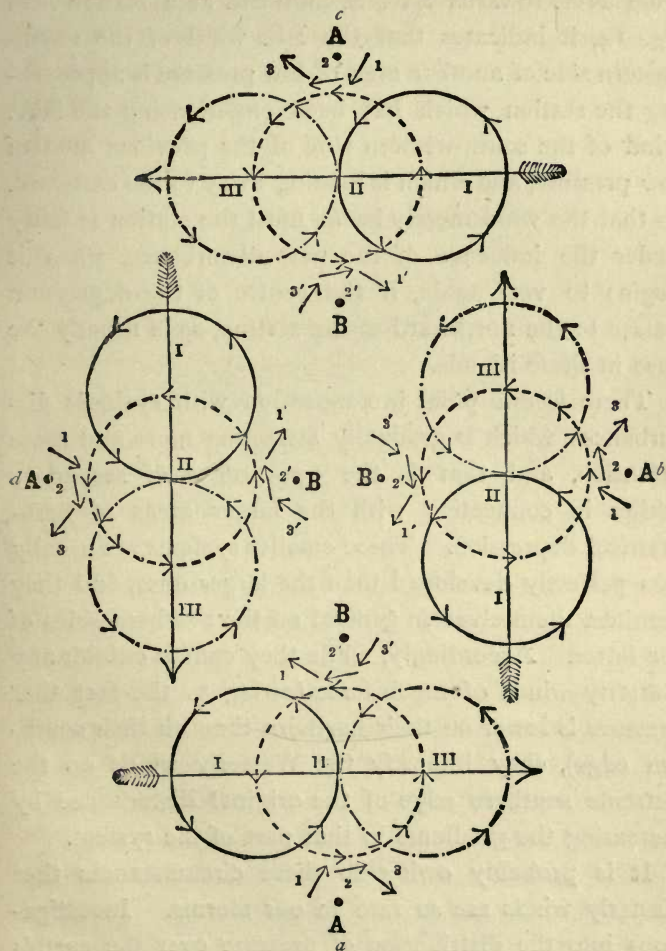


FIG. 14.

from NW. towards SW., S. and SE. at a station A in fig. 14, it indicates that the SE. wind of the north-eastern side of another area of low pressure is approaching the station which has been experiencing the NW. wind of the south-western side of the previous area of low pressure, and which is passing away to the eastward, so that the wind merely backs until the station is fairly under the influence of the new disturbance, when it begins to veer again, if the centre of the depression passes to the northward of the station, as is usually the case in these islands.

There is one point in connection with cyclonic disturbances which is gradually attracting more and more attention, and that is the appearance of secondary eddies in connection with the larger areas of barometrical depression. These smaller systems are usually less perfectly developed than the larger ones, and they manifest themselves in general on the southern sides of the latter. Accordingly, while they cannot exhibit any Easterly winds of much force (owing to the fact that pressure is lower on their northern than on their southern edge), they intensify the Westerly winds on the extreme southern edge of the original disturbance by increasing the gradients in that part of the system.

It is probably owing to these circumstances that Easterly winds are so rare in our storms. Investigations into the distribution of pressure over the earth's surface have shown that there is an almost constant deficiency of pressure in the neighbourhood of Iceland,

and so probably most of the depressions which cause our storms are simply secondary to a vastly more extensive permanent area of depression over the North Atlantic.

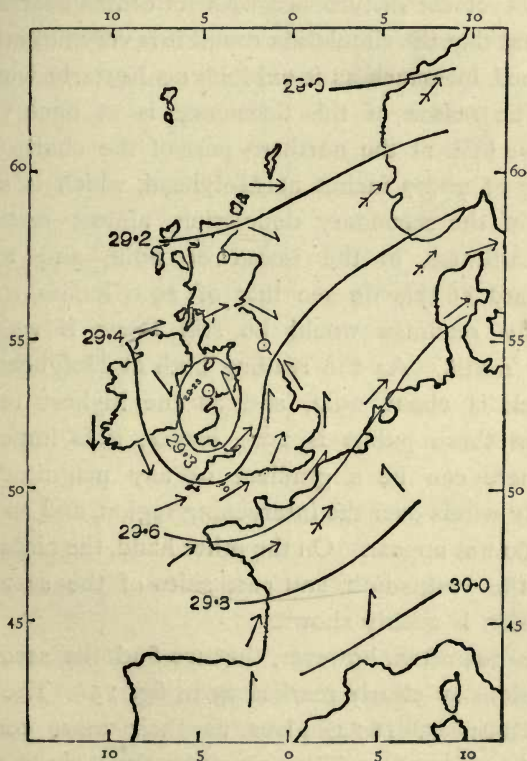


FIG. 15.—January 3, 1874 ; 8 A.M. Secondary depression.

It will be interesting to give a few instances of these 'satellite' depressions (as the French call them), to

illustrate what we have been saying, and fig. 15 (p. 81), for January 3, 1874, shows us on a small scale the conditions to which allusion has just been made as characterising many of our gales. We see that there is a small cyclonic disturbance with its centre near Holyhead, and that the circulation round it is very imperfectly developed, inasmuch as it exhibits no Easterly winds at all. The reason of this deficiency is at once visible when we look at the northern part of the chart. The reading of 29.23 inches at Holyhead, which is at the centre of the secondary depression, almost reappears over Caithness, in the isobar of 29.2, and to the northward of this we see that of 29.0 inches, so that evidently readings would be still lower if we went further north. As the reading both at Holyhead and at Wick is about 29.2, and as the highest reading between these points is 29.3 inches, it is impossible that there can be a gradient of any magnitude for Easterly winds over the intervening region, and so those winds do not appear. On the other hand, the circulation round the west, south, and east sides of the secondary depression is clearly shown.

It is not often, however, that we find the secondary depressions so clearly marked as in fig. 15. The chart for October 7, 1874, gives us their more common character (fig. 16). They manifest themselves simply by a loop in some of the isobars, and their effect is, as already described, to reduce the gradients on the side turned towards their primary, and to increase them on

the opposite side. We could hardly have a better example of this than that given in fig. 16. The strong NW. wind at Stornoway, and the SW. gales in the Skagerrack and in Denmark, show that the conditions for strong winds prevail generally, but over southern Scotland and central England nothing but light

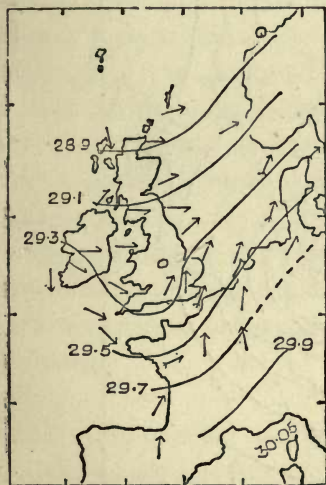


FIG. 16.—October 7, 1874; 8 A.M.
Secondary depression.

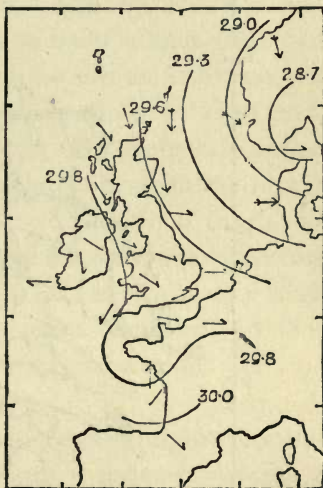


FIG. 17.—October 22, 1874; 6 P.M.
Secondary depression.

Westerly airs are reported. On the other hand, in the Channel and in France the isobars are crowded together, and heavy gales are the result.

Another instance is represented on fig. 17, for October 22, 1874, but here it is the North-westerly winds of the primary system that are reduced in force, on account of the fact of the secondary manifesting

itself on the south-west side of its principal. Owing to the apparent equality of pressure over the Bay of Biscay there are no gradients of consequence there,

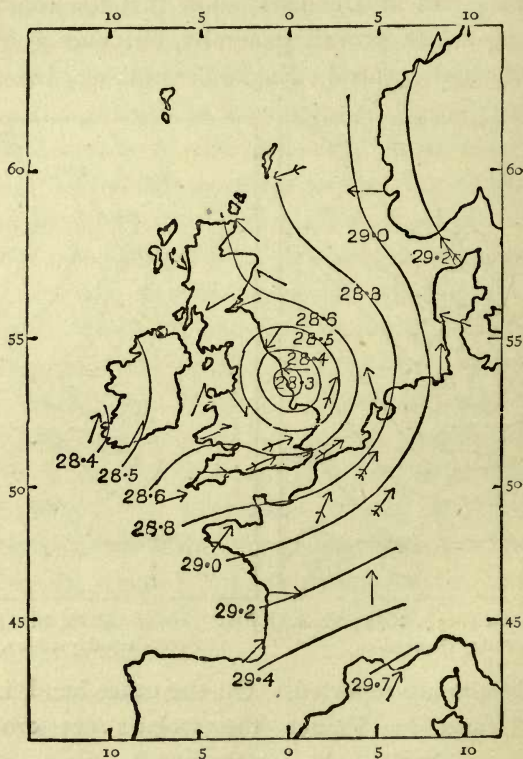


FIG. 18.—January 24, 1872 ; 8 A.M. Co-existing depressions.

and therefore no gales in connection with the smaller system, but, so far as direction is concerned, the circu-

lation round the smaller depression is very clearly marked.

At times it is hard to say which of the depressions is the primary and which the secondary, as there is apparently not much difference in size between them. This was the case on January 24, 1872 (fig. 18), when we see one depression, with central readings as low as 28.3 inches, near Scarborough, while another shows itself off Valencia. The result of the interference of these two systems is to produce a comparative calm between them, the winds being very light over St. George's Channel, while strong gales are blowing wherever this interference does not exist.

In treating of the interpretation of weather charts and of storm warnings, we shall show the use which can sometimes be made of these secondary cyclonic systems.

In this chapter we have considered the contrast between cyclonic and anticyclonic systems, or areas, as they are indiscriminately termed, and the character of the weather which accompanies each respectively.

We have learnt that, while anticyclonic areas move slowly, cyclonic areas travel more or less rapidly over the country, and moreover that their passage past a station presents marked features of difference in the weather experienced, according as the station lies on the right or left side of the path of the centre.

Lastly, we have found that cyclonic systems are not always isolated, but occasionally have what may be called secondary systems in connection with them, which exert a material influence on the gradients, and consequently on the winds belonging to the original disturbance.

CHAPTER VI.

THE MOTION OF STORMS AND THE AGENCIES WHICH
APPEAR TO AFFECT IT.

BEFORE we treat of the motion of storms it must be admitted, as will appear in the next chapter, that meteorologists are not at all agreed as to what the real causes of that motion are. It has not been satisfactorily determined to what extent the storm moves forward as a whole, or to what extent the advance observed is only due to the continued reproduction of the same phenomena at successive points, as is the case in wave motion.

The fact that storms advance over the earth's surface, with a motion of translation in addition to their own rotatory motion, has, however, long been known. The earliest notice of it which we can discover is an entry on a map of Virginia, published in 1747 by Lewis Evans, to the effect that 'all our great storms begin to leeward.' Franklin, in 1760, followed in the same strain, but it appears that his attention had been caught at an earlier period, in 1743, by the fact of his being prevented at Philadelphia, by the clouds brought by a

hurricane, from observing a lunar eclipse, while the eclipse was seen at Boston, which lies further to the north-eastward, before the storm came on. The reader hardly needs to be reminded that hurricanes and cyclonic disturbances in general are accompanied by an abundance of cloud. Along the eastern coast of the United States, therefore, the advance of storms from south-west towards north-east has long been a recognised fact.

The direction of the motion is different in different parts of the earth. Of storm tracks which are well made out, those of the West India hurricanes, in the earlier part of their course, are, speaking in general terms, from east-south-east to west-north-west: in the Indian Ocean, the Mauritius hurricanes advance at first from east-north-east to west-south-west, but both of these classes of storms generally recurve subsequently at a sharp angle, and advance towards the eastward. The typhoons of the China seas also at first move towards the coast from the eastward and subsequently recurve.

Over these islands, however, the motion of storms is not nearly so constant in direction as in the instances which have been cited, and, although as a general rule it may be said that our storms travel from the westward, there are many exceptions to this rule, and in fact storms can, and do, move from every point of the compass, but a motion from an easterly point is extremely rare.

It will be best to consider the usual directions of motion in connection with the causes which appear to govern them, and we shall also offer some remarks on the motion of anticyclones, and show what a contrast in this respect they present to the behaviour of cyclonic systems.

As regards the rate of motion, it may be premised that this varies very greatly, some storms travelling very slowly or even remaining apparently steady, while others are propagated with great rapidity. The rate of motion of the West India hurricanes ranges from ten to fifteen or twenty miles an hour in their early stages, but becomes accelerated in the latter portion of their path, while in these islands the motion has attained the prodigious speed of fifty miles an hour, February 12, 1869, an instance already cited, p. 65, and even seventy miles an hour, December 16, 1869, a velocity nearly equalled on the night of November 10-11, 1875, as well as on March 12, 1876.

It must be clearly understood that the rate of translation of the storm *has no direct relation to the velocity of the wind in that storm*, for the West India hurricanes exhibit almost the strongest winds of which we have any knowledge, and they travel slowly, while the rapidly moving storms just cited were not very exceptional as regards their violence. In Europe, however, it has been found, as a general rule, that the most violent storms do advance the most rapidly.

However, one of the greatest difficulties which meets

us, in the issue of Storm Warnings in these islands, is our almost total ignorance of the rate at which any given storm is travelling, until it has already moved over a considerable tract of country.

It is easy to cite instances of the motion of storms, and we shall select the two cases which have already been employed as illustrations of cyclonic and anti-cyclonic disturbances respectively, and trace their progress across the area of our weather maps, paying

attention mainly to the isobars and the wind.

Let us first take the storm of November 29, 1874. The earliest unmistakable signs of its approach (fig. 19) were at 8 A.M., November 28, when a rapid fall of the barometer at Valencia, with the Southerly wind, and the course of the isobar of 29.3 inches, showed that there must be an area of lower readings at sea, outside the coast.

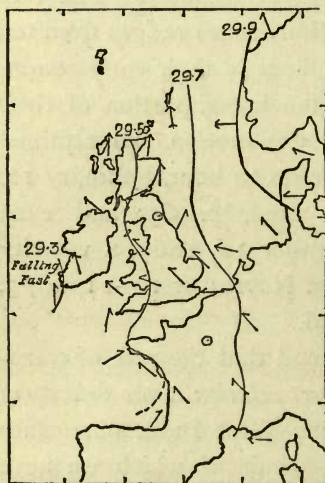


FIG. 19.—November 28, 1874 ;
8 A.M. Approaching depression.

Over the greater part of England the direction of the wind was South-easterly ; a common phenomenon on the approach of a serious storm, owing apparently to the in-draught of air towards the region of diminished pressure.

The next chart, for 6 P.M. on the same day (fig. 20), shows the central isobar (of 29.0 inches) over the south of Ireland, while the SE. winds over England have veered to SW., and the isobars, previously running nearly north and south, show a marked curvature. Even in Norway pressure has given way, the isobar

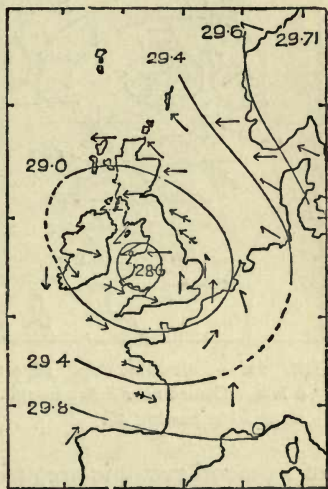
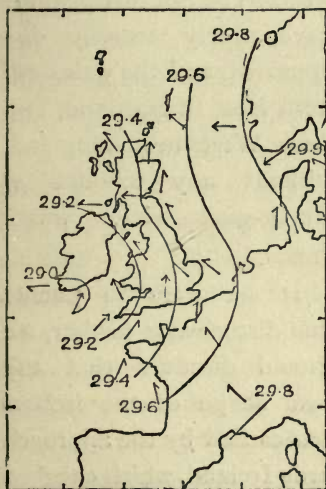


FIG. 20.—November 28, 1874; 6 P.M. Depression advancing. FIG. 21.—November 29, 1874; 8 A.M. Centre over Wales.

of 29.8 inches having taken the place of that of 29.9 inches on the previous chart.

During the night the storm made rapid progress, and at 8 A.M. (fig. 21) we have the conditions already described at p. 39, the centre of the storm lying near Holyhead, and the influence of the disturbance extending over the whole of Western Europe.

At 6 P.M. on the 29th (fig. 22) we find the centre of the storm near Newcastle, with a reading of 28.4

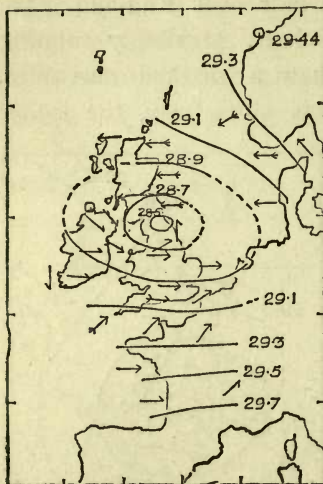


FIG. 22. — November 29, 1874 ;
6 P.M. Centre near Scarborough.
Depression passing off.

inches, while the general course of the isobars is that of an ellipse, with its longer axis stretching east and west. The Southerly winds have nearly entirely disappeared, and the gales are from East in Scotland, and from West over England, without any amount of North-west winds worth notice.

If we were to pursue this disturbance further, we should discover that the oval shape of the isobars was caused by the approach

of a second cyclonic area towards Ireland, which checked the rise of the mercury and reduced the gradients in the rear of the former system, and thus hindered the development of the North-westerly winds—a feature to which allusion has already been made at p. 65. In fact, the chart for the next morning exhibited two separate areas of depression, one over Ireland, the other over the North Sea, while the latter area showed evident signs of being filled up.

It is not necessary to quote other instances to prove

the fact of the motion of cyclones, and we shall now proceed, by way of contrast, to consider the motion, or rather the comparative absence of motion, in anticyclones, and shall take the period at the beginning of February 1874. It is not necessary to give more than the daily

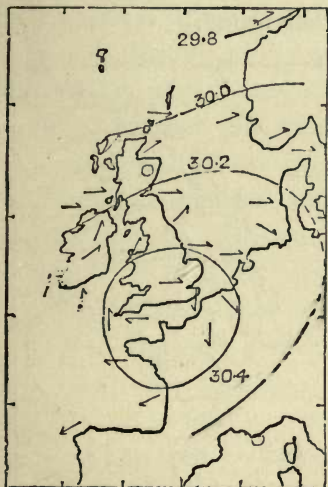


FIG. 23.—February 2, 1874 ; 8 A.M.
Anticyclone.

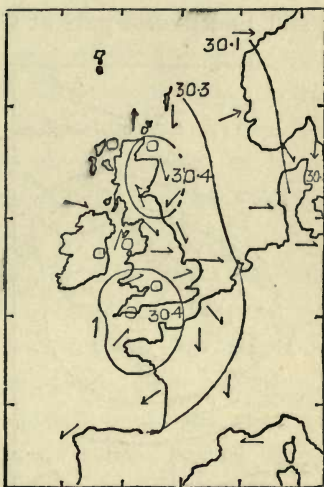


FIG. 24.—February 3, 1874 ; 8 A.M.
Anticyclone stationary, but changing in shape.

charts for 8 A.M., as the changes from day to day are very slight.

Fig. 23, for February 2, shows an area of readings above 30.4 inches over the Channel. In fig. 24 this has hardly changed its place, but a sudden rise of the barometer has taken place over the north of Scotland, so that we have two independent centres of high pressure

over our limited area. In fig. 25, for the 4th, the secondary anticyclone has vanished, and we have the conditions already cited at p. 40 as a typical anticyclone, and at the same time the effects of a cyclone outside the Shetlands are just felt on the coast of Norway, where the barometer has begun to give way, accompanied by a stiff South-west gale at Christiansund.

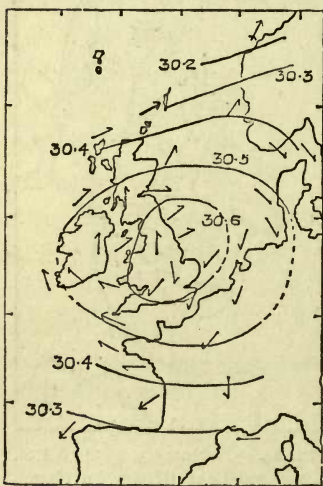


FIG. 25.—February 4, 1874; 8 A.M.
Original shape regained.

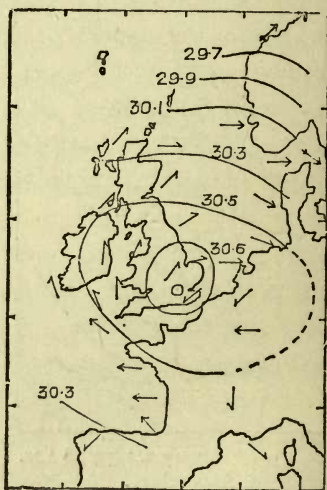


FIG. 26.—February 5, 1874; 8 A.M.
Anticyclone disappearing.

The last chart of the series, fig. 26, shows us the central isobar of 30.6 inches over the Eastern Counties, while all over the North Sea strong Westerly winds have appeared, owing to the advance over Norway of the cyclonic disturbance just mentioned.

In this case, therefore, which is a fair sample of the

behaviour of areas of high pressure, it is evident that the persistence of the conditions of high barometrical pressure over the south of England was as marked as the instability of the conditions of low barometrical readings was proved to be in the preceding instance. Anticyclones, however, do change their position, but it is needless to pursue the subject further in this place.

Before treating of the agencies which appear to rule the motion of cyclones, it may be well to say a word or two on the influences which appear to modify that motion, at least in the neighbourhood of these islands. We find that the storm path is much affected by the contour of the country. It is well known that the west coasts of Ireland and Scotland are bold and rugged. It has sometimes happened that a storm has advanced from the Atlantic to the coast of Kerry, but has returned, and, passing out to sea again, has moved northwards along the coast until it found the opening of Donegal Bay, and has then crossed Ireland along the tract of low land stretching from Ballyshannon to Dundalk, to the Irish Sea, where the centre often appears to be arrested for a while : or else the disturbance, clearing Ireland altogether, and crossing Scotland south of the Grampians, has passed out to the North Sea. In fact, we have already seen, from the phenomena of the Hallsberg tornado, p. 29, that the stratum of air affected by a storm is frequently very thin as compared with the entire depth of the atmosphere. We can therefore easily understand that eddies in the stratum

of air which is in immediate contact with the surface of the ground may be very much affected in their character and motion by the irregularities of that surface, which have a tendency to turn them aside.

It need hardly be pointed out that the susceptibility of storms to such a deflecting influence, exerted by the contour of the country, bears some resemblance to the behaviour of smoke-rings, which are deflected from their course by obstacles placed in their path, although they may not actually come in contact with the obstacles. Remembering that the depth of storms is insignificant compared with their lateral extent, we may to a certain extent compare cyclonic disturbances to smoke-rings, although the constitution of the two phenomena is widely different.

As regards the actual direction of motion of cyclones, when we come to examine a series of charts extending over a wide area, like those of Captain Hoffmeyer and others, for Europe and the Atlantic, it is found that the cyclones have a tendency to move round the anti-cyclones, but it is almost impossible to follow out these motions fully when we can deal only with the limited area of our own charts. It is, however, from this mutual action of the areas of high and low pressure on each other that we gain some notion of the coasts which are likely to be visited by a storm, of the direction which that storm will take, and of the quarter whence the wind in that storm will blow hardest.

If we find the readings highest over Ireland, the

depressions will sweep down over Scandinavia or even over the North Sea, in a direction from the northward to the southward, giving us Northerly gales along the east coast of Scotland and England, owing to the fact that the steepest gradients will be on their western sides. These areas of low pressure will follow each

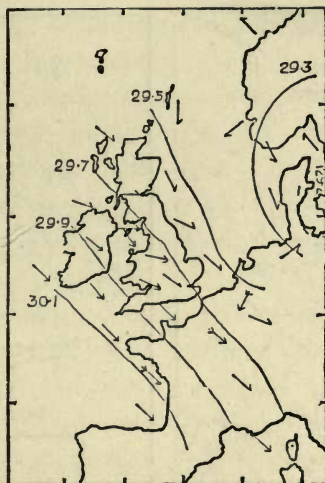


FIG. 27.—November 17, 1874; 8 A.M. Pressure highest in south-west. Depression disappearing over Denmark.

other until by some means or other the excess of pressure in the west has been reduced.

Figs. 27–30 afford very good examples of the above conditions. We start on November 17, 1874 (fig. 27), with readings highest in the south-west, general North-west winds, and a definite depression existing over Denmark, marked by the isobar of 29.3 inches. At

the same time a backing wind at Stornoway and the SSE. wind at Christiansund show that a fresh disturbance is not far off. Fig. 28, for next morning, November 18, still exhibits the traces of the cyclonic disturbance over Denmark, but the lowest readings there are about 29.7 inches, showing a rise of half an inch in

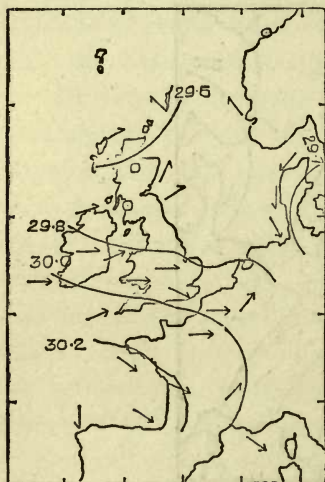


FIG. 28.—November 18, 1874 ;
8 A.M. New cyclonic disturbance
appearing in north.

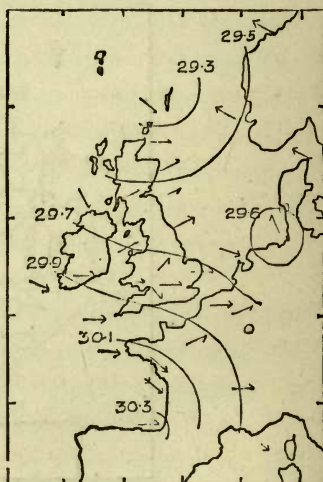


FIG. 29.—November 19, 1874 ;
8 A.M. Depression over Heligo-
land. A third appearing in the
north.

pressure. All over the chart, except just in the southwest, the course of the isobars is changed, and the advancing depression is perfectly visible, and has produced its effects on the winds, causing them all to 'back' to W. or SW., and even to SE. in Shetland.

The morning of the 19th (fig. 29) shows us a great change; the area of low pressure, which lay off Shetland on the previous day, has advanced rapidly southwards, and lies over the mouth of the Elbe, while another similar system has appeared over Shetland. Each of these independent disturbances has its own atmospheric circulation.

The last chart of the series is fig. 30, for the 20th. In it we see the last-named depression situated in nearly the exact locality of its predecessor, over northern Germany, while the disturbance of the winds at the northern stations shows that the perturbations are not yet at an end. The rise, however, of the barometer over Holland indicates that the general distribution of pressure is undergoing a change.

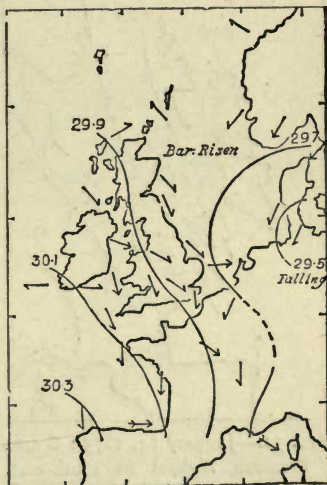


FIG. 30. — November 20, 1874 ; 8 A.M. Depression disappearing over Denmark.

In this case, therefore, we have a succession of cyclonic disturbances chasing each other for several days, along similar paths, while the region of highest pressure lies in the west.

If the highest readings be over France, the path of the cyclonic disturbances will run from west to east,

across the British Isles, and the wind will blow hardest from the Westward. When the centre of the anti-cyclone lies over England we find that the storms hardly affect our stations at all, but pass outside the north coast of Scotland, producing strong Westerly gales on the Norwegian coast, above the sixtieth parallel, at

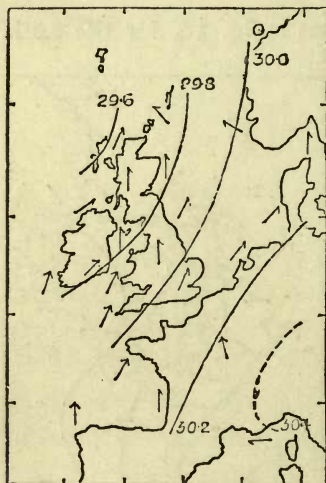


FIG. 31.—January 14, 1875 ; 8 A.M.
Pressure highest in south-east.
Depression off Hebrides.

Christiansund, Bodö, and northwards. It is needless to cite instances of these conditions; they are already admirably illustrated by figs. 25 and 26 (p. 94).

When the area of high pressure is located more to the east or south-east, over Denmark or Germany, the cyclonic systems cannot make good their footing over these islands at all, but pass from south to north outside the Irish and Scotch coasts, producing gales from the Southward on our

shores. Such storms frequently only appear in the west of Ireland, and are thence propagated to the Hebrides, Orkneys, and Shetlands, without extending to the English coasts.

A very good instance of this type of weather occurred in the beginning of the year 1875. Fig. 31,

for January 14, shows us the barometer highest over Switzerland, and the isobars running NE. and SW. across these islands, while a depression is just visible off the NW. coast of Scotland. Fig. 32, for the 15th, shows but little change of pressure over Central Europe, but a fresh disturbance has appeared off the west coast

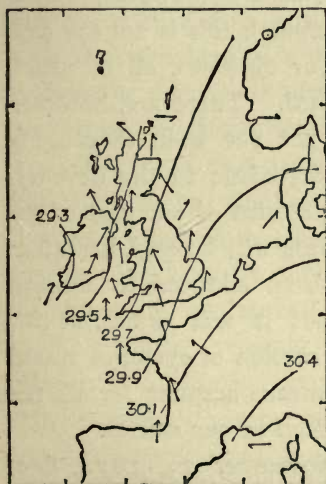


FIG. 32.—January 15, 1875; 8 A.M.
New disturbance off west coast of
Ireland.

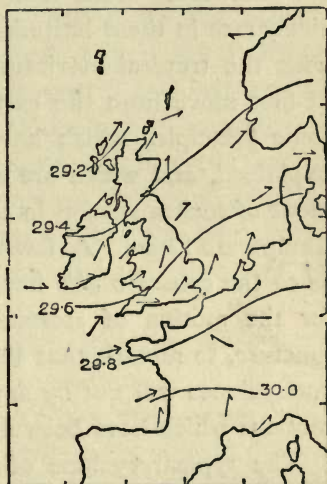


FIG. 33.—January 16, 1875; 8 A.M.
Pressure highest in south.
Depression off NW. coast of
Scotland, moving eastward.

of Ireland, causing the winds to back to S. and SE., and blow with the force of a gale. Fig. 33, for the 16th, shows us this second disturbance in the position of its predecessor of the 14th, but, pressure having given way over Norway, the conditions are altered, and

the region of the highest barometrical readings is transferred to Spain.

We have hitherto spoken of the cases when pressure is highest in the west, south, and east respectively, but the anticyclone must sometimes lie to the northward of us, and then, if ever, should the disturbances advance from the eastward. Such a movement is, however, excessively rare in these latitudes, though this is not the case with the tropical hurricanes or cyclones, all of which at first move from the eastward. There are, however, some principles which have not yet been thoroughly explained, and which are antagonistic to the development of such a motion in the storms of our part of the Temperate Zone. A few words will be said, hereafter, as to the causes which have been adduced to account for the motion of storms, but it will suffice, at this juncture, to remark that the motion of cyclones round anticyclones will not by any means account for all the motions which have been noticed in our storms.

The typical cyclone of November 29, 1874, figs. 19-22 (pp. 90-92), to which reference has frequently been made, did not skirt round the region of high pressure on our charts, but travelled directly towards it. In this case it is possible that a study of the weather over more extensive charts—such as those of the North Atlantic, now being published by our Office—might throw more light on this question of motion.

While discussing the motion of storms, it may be interesting to trace the path of a very erratic disturbance

which visited these islands in April 1872, and the course of which has been followed out with the aid of the continuous records at our self-recording observatories. The following seven charts (figs. 34-40, pp. 104 and 105) show the successive positions of the central disturbance, and fig. 41 gives its track for the entire period. It came in over Ireland and retreated along its own path again. That it did not advance as far as the Straits of Dover is clearly shown by the records at Kew, and that it passed first on one side and then on the other of Falmouth is indicated by the records at that observatory, which prove by the direction of the shifts of wind, on the same principles as are explained in Chapter V., that the path of the centre lay first on the southern and then on the northern side of the station.

This storm presents us also with the rare phenomenon of an advance from the eastward. As far as we can at present form an opinion, this latter condition depends on circumstances of pressure far outside the area of these islands, or even of that embraced by our weather charts. It is needless to say that such a storm as that just described afforded a striking instance of failure of warnings, as will be explained in Chapter IX. (p. 137).

The storms of which we have been treating have all exhibited motion more or less rapid, and in various directions, but it sometimes happens that areas of low pressure are stationary for two or three days together

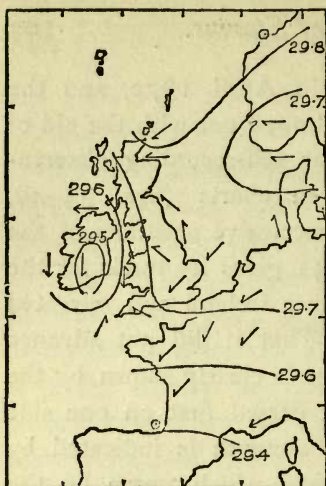


FIG. 34.—April 20, 1872; 8 A.M.
Centre of disturbance near Waterford.

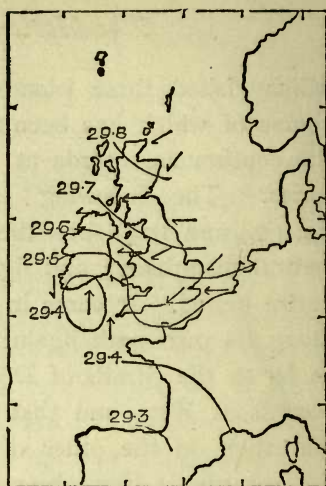


FIG. 35.—April 20, 1872; 6 P.M.
Centre of disturbance off south coast of Ireland.

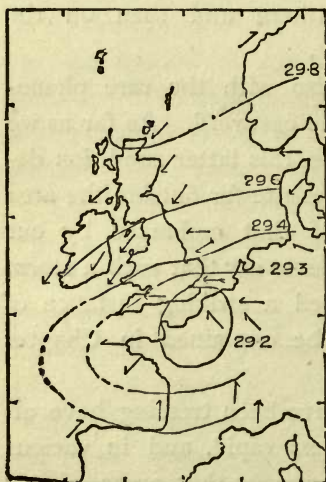


FIG. 36.—April 21, 1872; 8 A.M.
Centre of disturbance near Havre.

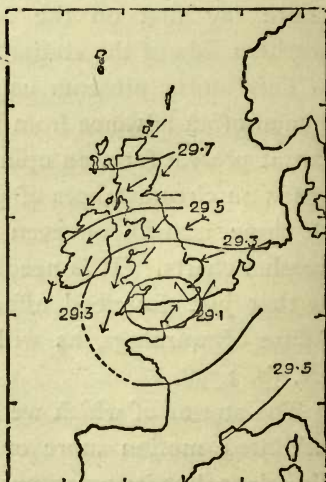


FIG. 37.—April 21, 1872; 6 P.M.
Centre of disturbance near Portsmouth.

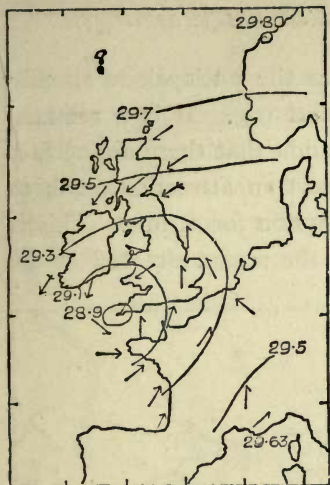


FIG. 38.—April 22, 1872; 8 A.M.
Centre of disturbance near Penzance.

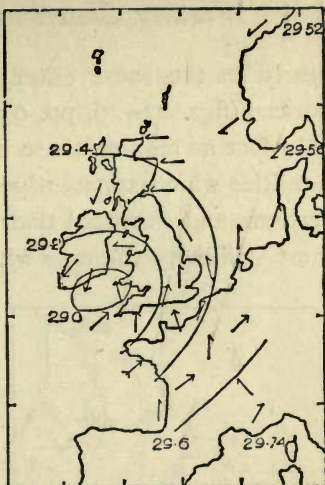


FIG. 39.—April 23, 1872; 8 A.M.
Centre of disturbance off south coast of Ireland.

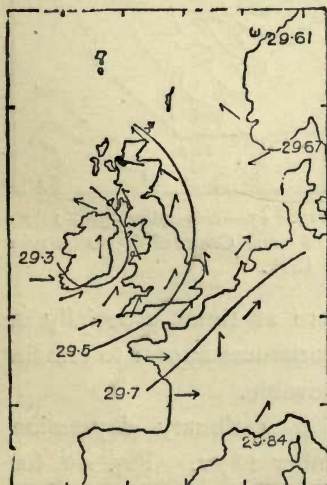


FIG. 40.—April 24, 1872; 8 A.M.
Disturbance passing off over Ireland.



FIG. 41.—April 20–24, 1872.
Path of disturbance.

nearly to the same extent as the anticyclone already noticed (figs. 23-26, pp. 93 and 94). It is a remarkable fact as regards these islands that there are certain localities which apparently exert an attraction on these systems, and so retard their motion for a time. This is most strikingly the case with the region situated at the

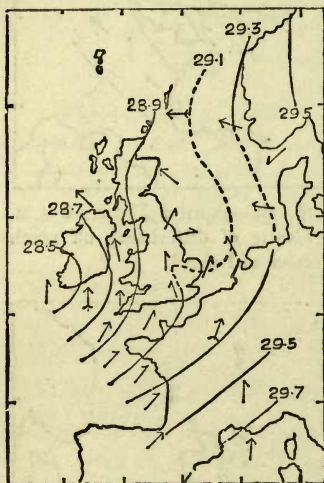


FIG. 42.—November 30, 1872 ;
8 A.M. Depression appearing off
Valencia.

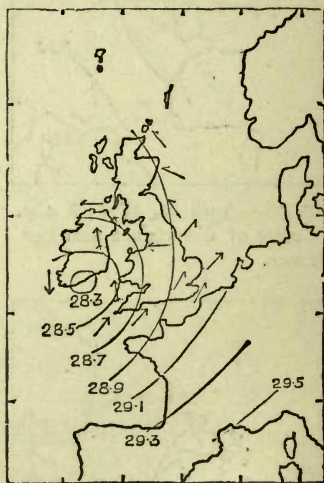


FIG. 43.—November 30, 1872 ;
6 P.M. Centre of depression near
Cork.

entrance of the Channel, where at times, especially in the early autumn, cyclonic disturbances appear to remain for days together almost immovable.

A very good instance of a stationary depression occurred at the end of November 1872. Fig. 42, for November 30, at 8 A.M., shows us the isobar of

28.5 inches over the south-west of Ireland. There is nothing else very remarkable, except that readings are generally very low, and that a secondary depression appears off the coast of Lincolnshire. Fig. 43, for 6 P.M. on the same day, exhibits the centre of a storm over Cork, but conditions otherwise do not show much

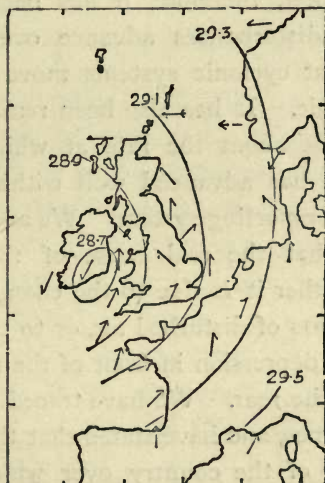


FIG. 44.—December 1, 1872; 8 A.M. Centre of depression nearly in same place, but depression filling up.

change, except that pressure has given way considerably over France.¹

Fig. 44, however, for 8 A.M. December 1, shows us the centre of the cyclonic area in nearly identically the same spot as it had occupied fourteen hours previously

¹ In 1872 we did not receive 6 P.M. reports from Norway, so that portion of the chart is blank.

but the whole system is being filled up, for the lowest reading, indicated by an isobar, is 28.7 inches, while 28.3 inches was the minimum in fig. 43.

This disturbance subsequently took a course to the SSE., and passed on to the west of France.

In this chapter, therefore, it has been shown that atmospherical disturbances advance over the earth's surface, and that cyclonic systems move more rapidly than anticyclonic. It has also been remarked that we know very little about the rate at which a storm is moving until it has advanced well within the area of our telegraphic reporting system. We are also virtually ignorant of what the real cause of this motion of storms is—whether it is due to the change of position of the entire mass of disturbed air, or to the continuous production of a depression in front of the storm while it is filling up in the rear. We have traced some cases of motion of cyclones, and have stated that this is modified by the contour of the country over which they have to pass, but that it appears to be regulated in great measure by the position of the anticyclonic areas in the neighbourhood.

CHAPTER VII.

THE USE OF WEATHER CHARTS.

IF we come to consider what is the practical use, to an ordinary observer, of weather charts, giving, as they do, a representation of past conditions of weather, it will be necessary to recapitulate briefly the results to which we have been led in the several preceding chapters, and then to enumerate some of the general principles on which a judgment is formed as to coming weather, when the observer knows by the study of a chart what conditions have been prevailing elsewhere. Subsequently some of the theories will be mentioned which have been propounded to account for the origin and motion of storms, and, lastly, we shall allude to the ideas which are entertained by some meteorologists as to a periodicity of rain and of storms, and as to a connection between disturbances in the gaseous envelope of the sun, and those which take place in our own atmosphere.

It will be useful in the first place to summarise briefly the principles which we hope have been established in the preceding chapters.

Chapter I. has been devoted to an account of the materials, in the way of observations, with which we have to construct our edifice.

In Chapter II. the wind has been discussed, as the atmospherical phenomenon which is most directly related to weather. It has been shown that wind is always connected with some disturbances of the pressure of the atmosphere ; its existence being due to the tendency of an elastic body, like the air, to regain the condition of equilibrium from whence it has, by any means, been disturbed, while its motion is regulated by certain fixed laws.

The subject of Chapter III. is the barometer, as being the instrument by means of which the amount of atmospherical pressure, and therefore of its disturbances from time to time, is measured. It is shown how the distribution of pressure on a weather map is indicated by the isobars, and how there are two grand types of disturbance of atmospheric equilibrium, named respectively cyclonic and anticyclonic, according as the pressure is locally either in defect or in excess of its average value over the area represented in the special chart in question. These two types of disturbance are characterised by different features, among which the most striking is the contrast in the direction of motion of the wind.

In Chapter IV. gradients have been explained, and it has been shown that the distribution of pressure, as measured by the gradients, is the best guide we have

towards a knowledge of the laws of wind motion, and therefore, in some degree, towards a knowledge of coming weather. It has, however, been stated that there are apparently agencies other than the distribution of pressure which influence the force of the wind, but that their precise nature has not yet been ascertained. It has also been pointed out that the phrases 'gradients for such and such winds,' &c., are nothing more than the expression of the laws of wind motion in a practical form.

Chapter V. contains a closer examination into the principal features of cyclonic and anticyclonic systems respectively, and into the character of the weather which accompanies each. It states that, while anticyclonic areas are usually stationary or move slowly, cyclonic areas travel more or less rapidly over the country, and shows that their passage past a station presents marked features of difference according as that station lies on the right-hand or left-hand side of the path of the centre. This has been illustrated by the continuous automatic records of some of the self-recording observatories in connection with the Meteorological Office, and it has been shown how the usual changes of wind are explained by this motion.

It has also been explained that cyclonic systems are not always isolated, but have occasionally what may be called secondary systems in connection with them, which exert a material influence on the gradients,

and consequently on the winds belonging to the original disturbance.

Finally, Chapter VI. has been devoted to the motion of atmospherical disturbances, and there it has been explained, at more length than in the preceding chapter, that cyclonic systems move more rapidly than anticyclonic. Some cases of the motion of storms have been traced, and it has been shown that, while we know very little of the rate of motion of a storm before it arrives, we can frequently form a conception of the probable direction of motion of the storm. This motion is affected by the contour of the country over which it passes, and it appears in great measure to be regulated by the position of the anticyclonic areas in the neighbourhood.

The least consideration of the principles just enumerated will abundantly show that the weather prevailing over any district on a given day is clearly affected by, if it may not be described as the result of, the conditions prevailing in the districts round about, so that, by observing what those conditions have been for some time back, we are enabled to form some opinion as to the weather which we are experiencing, and which is related to those conditions, whether it is likely to be permanent or transient in its character, and, if transient, in what way it is likely to change.

It is hardly necessary to say that the fresher the information is the better, but, owing to the cost, it is

not possible in this country to follow the example of the United States, and send out by telegraph, in all directions, the entire mass of figures in the Daily Weather Reports, in order that it may be published simultaneously in every large town. Practically, in these islands the readers of newspapers and the subscribers to the Daily Weather Report cannot see their charts until several hours, frequently even an entire day, after date.

Such information, however, can generally be turned to very good service, if rightly used, and we shall take the case of an observer resident not far from London, and see what he can do with it.

It has already been explained that most of our disturbances travel from the westward, and, as they take a certain time to advance over the distance which separates the east of England from the west of Ireland, we can learn, by studying the chart for the previous day, what conditions were then existing at the western stations, and consequently can gain some idea of what is likely to be the result of the changes which we notice by our own local observations, instrumental and otherwise.

If, for instance, the barometer at our station is high and steady, with dry weather and light winds, either in winter or summer, we may form a general notion that the type of weather is anticyclonic, and, as this type is peculiarly permanent, we may feel sure that any change will give us at least several hours' notice of its coming,

by alterations in instrumental readings, occurring over some part of the district covered by the Reports. The study of the charts in this case is the more important, because frequently, at such a time, 'cirrus' or 'mare's tail' clouds appear in the sky, which are usually the precursors of coming wind; and change of wind in such a case means change of weather. The charts then will show whether or not this change of weather had made its way down to the earth's surface at any place on the previous day within the district just referred to.

In the case of cyclonic conditions, we have already learnt that it will not do to trust implicitly to the fact of storms advancing from the westward, but, on the other hand, some ideas have been advanced by means of which we can, at least in some cases, forecast the probable direction of motion of a storm. At any rate we are usually able to learn, from a careful study of the chart, whether we have to deal with disturbances on a large or a small scale, and, accordingly, whether the changes in progress indicate lasting, or merely temporary conditions of weather.

These charts are therefore useful helps to the local observer, and will be found so by those who *study them regularly, and combine with that study careful and systematic observations of their own instruments, and of local weather*; but for the purpose of judging whether a particular afternoon will be wet or fine, which is all that the public generally care to know about weather, it is obvious that charts which are necessarily twenty-

four hours old in many places cannot be of much service. Moreover, the phenomena which we include under the general term 'weather' often depend in great measure on the nature and conformation of the ground in the neighbourhood of the observer, so that one place will be much more liable to rain during disturbed weather than another, while a second may exhibit a greater tendency to the formation of fog at a calm period than an adjacent district. As, therefore, such exceptional tendency is confined to each special locality, and does not belong to the phenomena produced at all stations by the system of circulation prevailing at the time, it is necessary that the observer who endeavours to forecast probable weather should seek to ascertain under what conditions such peculiarities manifest themselves, as it would be useless to apply merely general rules in order to interpret the meaning of phenomena of a purely local character.

On the whole, it must be said that our insular and exposed position precludes us, in the present state of our knowledge, from the possibility of issuing forecasts of future weather with such confidence as some of our neighbours on the Continent of Europe, not to speak of the staff of the Chief Signal Office in Washington, which has attained a marked proficiency in weather prediction. We shall, however, in Chapter X. state what is being done in this direction.

Let us now examine in what manner the knowledge we have gained would enable us to issue storm warnings

to the coasts. In the first place, we can in many instances learn from the general conditions of wind, &c., in fact, of weather as a whole, what will be the character of the changes likely to occur, and in what direction they will propagate themselves.

We then notice the conditions of pressure as shown by the barometer, what its changes are, and whether any changes which may manifest themselves at any spot are traceable at adjacent stations, and in what degree, so that we can gain some idea of the extent of the disturbances which are approaching.

We next see in what degree the barometrical changes are borne out by the wind, both in direction and force ; in fact, we often get earlier intimation of approaching change of weather from abnormal features in the direction of the wind, than from the barometer readings taken by themselves.

Temperature, too, must be looked to, for as a general rule, in winter, if the temperature has been very low, even though the wind has been Southerly, we need not fear a Southerly gale until the advancing depression has exerted a marked influence in raising the temperature.

We have then the reports as to weather at the different stations, and the deficiency of information of this nature has been amply explained in Chapter I. To this class of observations belong reports of the character and motion of clouds, and of the clearness or mistiness of the air. Each of these latter may be, in its way, a prognostic of storm ; the former, an unnatural clearness,

being a very bad indication before the storm has actually reached us and affected our winds, while the latter, mistiness, is often the immediate forerunner of coming rain, and sets in when the wind in an advancing cyclonic system has begun to blow from the South or South-east, or more especially on the ridge of high pressure or debateable ground, which lies between the NW. wind of a *retreating*, and the SE. wind of an *advancing*, area of low pressure.

Reports of the Aurora are also very useful as corroborative evidence. The winter of 1875-6 was remarkably free from Westerly winds, *i.e.*, from cyclonic disturbances passing to the northward of these islands, and was also remarkable for the rarity of reports of the Aurora.

It is, however, obvious that we, in the Meteorological Office, labour under prodigious disadvantages in attempting to issue warnings for the United Kingdom. Interest therefore attaches itself to the attempts which we are making from time to time to draw conclusions from the experience of past weather which may be useful to us in forming opinions on what is to come.

Attention has already been drawn to cyclonic disturbances which follow each other along the same track as long as the general distribution of pressure remains unchanged, and it has also been stated at p. 15 that cyclonic disturbances travel across the Atlantic for long distances, if not from shore to shore. This is abun-

dantly proved by the fact that steamers, when outward-bound to America, often meet a succession of such cyclonic systems on their way towards Europe, and, when homeward-bound to England, often run for a certain time with such systems, so that in the former case the changes in the instrumental indications, as well as in winds and weather, are much more rapid than in the latter, on the simple principle that if walking in a crowded thoroughfare you meet many more vehicles than you pass or than overtake you. We shall return to this subject of the advance of storms from America at p. 183.

If, then, these disturbances are frequently travelling in succession over the Atlantic, it is evident that we in these islands must at times encounter a series which bears a close resemblance to a series which has preceded it, as to the general character of the areas of depression themselves, and as to the intervals which occur between them. This we have noticed in our own weather on various occasions, and the parallelism has been found to hold good for as many as eight days together.

As to the theories which have been of late years propounded to account for the origin and motion of storms, no attempt will be made to discuss them, but the broad features of some of them will be indicated in a very cursory way.

Professor Mohn, the Rev. W. Clement Ley, and others attribute the generation and motion of storms

to the condensation of moisture in the form of clouds, resulting in rain. This condensation takes place principally in front of the storm, and, so to speak, draws it on.

Mr. Thomas Belt and Professor Reye account for the origin of the storm by the existence of a condition of unstable equilibrium in the atmosphere; a cold stratum being situated at some height above the ground, if the air at the earth's surface becomes heated, it must eventually force its way through the superincumbent colder layer, and the upward current thus generated will be the core of the resulting cyclone. Professor Reye goes so far as to say that the storms of the largest dimensions experienced in these latitudes are substantially analogous to the smallest waterspouts or dust-whirls we can observe.

In direct contradiction to this view, M. Faye has long propounded the view that cyclones are vortices descending from the upper regions of the atmosphere to the earth's surface, and that their motion is that of the upper current.

Lastly, Mr. Meldrum and others consider that cyclones are generated in the space intervening between two currents, which themselves are tangents to the nascent cyclone. Thus, in the North Temperate zone, the conditions which would give rise to the cyclones are those of Easterly winds on the northern side of Westerly winds. The reader need hardly be reminded that every perfectly developed cyclonic

disturbance here must have East winds in the north and West winds in the south.

It is clear that when 'doctors differ' to the extent indicated in the above sketches of the different theories, the world in general must be content to wait patiently for a complete theory of weather to be developed.

Before we leave the subject altogether, it will perhaps be interesting to see the extent to which we are able to forecast the weather for longer periods than a day or two. Attempts have not unfrequently been made to predict the seasons for a long period in advance, but without much success hitherto. One great cause for failure is that accurate meteorological records do not extend beyond the beginning of the present century at more than a few stations, and at these we are unable altogether to eliminate the local influences. Thus, it is hardly possible to say what has been the approximate temperature of these islands for more than forty years—a period far too short for the definite recognition of a cycle. The shortest of such cosmical cycles which has been determined is the sun-spot period of $11\frac{1}{9}$ years, according to Wolf, and there are indications of far longer periods, such as 33 years, or even $69\frac{1}{3}$ years, according to Hornstein.

Of late years Mr. Meldrum, of the Mauritius, has shown that the cyclones, for which that district of the Indian Ocean enjoys an unenviable notoriety, have been more frequent in some years than in others, and that these epochs of maximum frequency occur at

intervals of about eleven years, coinciding with those of maximum sun-spot frequency.

This agreement is very important, and it appears to be corroborated by an examination of the rainfall at several stations which has been conducted by Mr. Meldrum and others. The results, for the comparatively short period to which they refer, are striking, and are sufficient to show that a periodicity is traceable in the weather of the Southern Indian Ocean, which is suggestive of a relationship between the changes which take place on the sun's surface and the phenomena of our own atmosphere.

It will at once be asked, Why has not this periodicity, if it exists, been detected long ago by an examination of European records, which are far more complete than any existing for the Indian Ocean? The answer to this is twofold.

In the first place, we are pre-eminently in the region of the variable winds, and our storms are not nearly so regular in their type as those of the Mauritius, where almost the sole type of storm is the true tropical cyclone with its concomitant rainfall. It is next to impossible in this country to keep a record of all the storms which pass over us. We have already seen that the existence of conjugate storms is not unfrequent, two or even three systems of disturbance being traceable at one time within the limited area of the United Kingdom. Are these one single storm or several? and how should they be counted in a catalogue? Rain

also cannot be taken as a sign of the frequency of wind storms in a year; for although we know that warm winters are invariably wet and stormy, and, moreover, that cyclonic disturbances are accompanied by rain at all seasons, yet it cannot be asserted that the almost constant rain of 1872, and the recurrence of floods in 1875, were in any way related to storms of wind, though their connection with the presence of areas of depression over these islands is indisputable.

There is, however, in the second place, a far deeper reason for the non-discovery of these cycles in any chance series of rainfall records. The sun passes through phases of greater and less activity, and the terrestrial phenomena corresponding to the epochs of the former character are excessive evaporation in some parts of the globe, and consequent excessive precipitation in others. We must therefore ascertain in what districts we are to look for the one and in what for the other of these phenomena respectively.

It may be said at present that the precise mode in which the sun exercises his action on our atmosphere has not yet been explained, and, as far as the climate of western Europe is concerned, the warmest adherents of sun-spot influence must admit that observations of the sun's surface cannot as yet be depended on as a sound basis for prophecy of coming weather.

That this assertion cannot well be disputed appears from the figures which follow.

WINTER HALF-YEAR.

	Temperature.	No. of Sun-spots.
1876-7	43.7	13
1877-8	43.4	8
1878-9	39.3	3
1879-80	41.4	24
1880-1	40.0	44
1881-2	43.7	64
1882-3	41.8	74
1883-4	43.9	105
1884-5	42.2	58
1885-6	40.2	31
1886-7	41.7	21

The first column gives the mean temperature of the entire United Kingdom for the six months October-March, for the last eleven years, and the second gives the number of sun-spots observed at Kew during the same period.

No approach to concordance is traceable between the two columns of figures.

If we go further afield and compare the general temperature of the globe, at least the closest approximation to it which is attainable, with the sun-spot curve for the thirty-five years ending with 1875, as has been done by Dr. Köppen¹ (fig. 45, p. 124), we see that, though for some part of the time some of the temperature curves appear to agree with the curve of sun-spots, the accordance in one hemisphere is associated with a striking discordance in the other.

¹ *Zeitschrift der österreichischen meteorologischen Gesellschaft*, Bd. xvi. p. 149.

The figures which I have cited therefore support the statement that the precise nature of the relation between what we may call solar and terrestrial weather has not as yet been demonstrated.

As regards the whole question of prediction of the

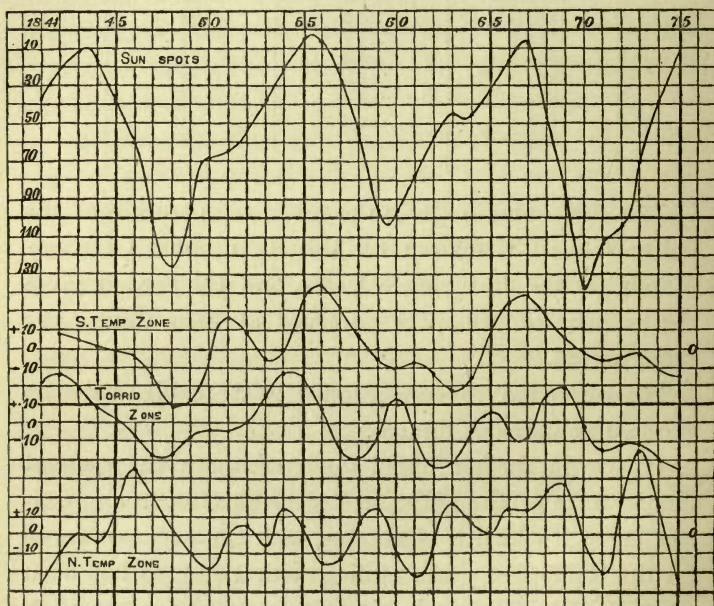


FIG. 45.—Diagram showing for the period of thirty-five years, 1841-75 inclusive, the number of sun-spots and the average temperature of the Torrid and two Temperate Zones.

seasons, either by sun-spots or by any other means, the same author, Dr. Köppen, has published several papers 'On Protracted Periods of Weather,' devoting

his attention especially to severe winters, and he gives the following summary of his results¹:—

‘The main feature of the entire investigation has been to prove that, for certain intervals, strongly marked periodical influences make their appearance and then vanish entirely, at times being replaced by others of a totally different character. No law has as yet been discovered for these changes, and so the outcome of the inquiry is on the whole negative, and indicates that all forecasting of the seasons is the merest guesswork.’

We may therefore conclude that at the present date there is no immediate prospect of any one being able to state what the character of a future season will be, much less to tell a farmer in spring what crops he should put in with a prospect of a favourable period for the harvest.

¹ *Zeitschrift der österreichischen meteorologischen Gesellschaft*, Bd. xvi. p. 196.

CHAPTER VIII.

THE DISTRIBUTION AND PERIODICITY OF GALES.

BEFORE we treat of storm warnings and the general prediction of weather, it may be interesting to state what has been ascertained as to the frequency of gales on different parts of our coasts, and also as to their periodicity, that is, the tendency which they exhibit to recur at distinct seasons.

As regards their local distribution, a table has recently been prepared in the Meteorological Office showing for each month, and for each quadrant of the compass, the total number of gales, and also of severe gales, for the different parts of the coast. The statistics refer to the fifteen years 1870-85. The coasts are divided into ten districts, as shown in the subjoined table.

It is not necessary to give the details of the table in such a book as this, and accordingly the monthly percentages of the annual totals, and the totals themselves, are all that will be reproduced, without discriminating between the different directions of the wind.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Totals.
The Shetlands .	16	13	11		1	1	2	3	6	13	14	15	281
Scotland, East .	15	13	12	4	1	0	0	3	6	15	16	13	229
Scotland, North-west	17	14	15	3	1	0	1	1	5	13	16	13	275
Ireland, North .	16	14	15	3	1	1	1	2	4	13	15	13	198
Ireland, South-west	21	14	10	5	2	1	1	2	6	10	15	12	277
England, North-east	16	9	16	4	1	2	3	3	5	14	15	11	172
England, East .	22	8	10	4	0	0	0	3	4	14	18	14	160
England, South .	15	8	8	5	2	1	1	7	7	14	17	16	190
England, South-west	15	12	10	6	2	2	1	5	6	13	15	13	328
The Irish Sea .	18	10	10	3	1	1	1	3	6	14	17	14	265

The table bears internal evidence that the number of gales bears a certain proportion to the number of stations in each district from which reports have been obtained. The figures have been compiled from the Returns of the results of Storm Warnings which are prepared every year. From these Returns the north-west of Ireland has been excluded, inasmuch as no storm warnings have ever been sent to any point, except Galway, situated between the Shannon and Malin Head. Accordingly, the number of reports of storms which were collected from that region before the establishment of Belmullet and Malin Head as reporting stations was not great. This is the main reason why in the column of totals the north of Ireland comes only seventh in point of frequency, instead of taking a position between Ireland SW. and Scotland NW., corresponding to its geographical situation.

It will be seen that the entrance of the English Channel heads the list of frequency. This is mainly

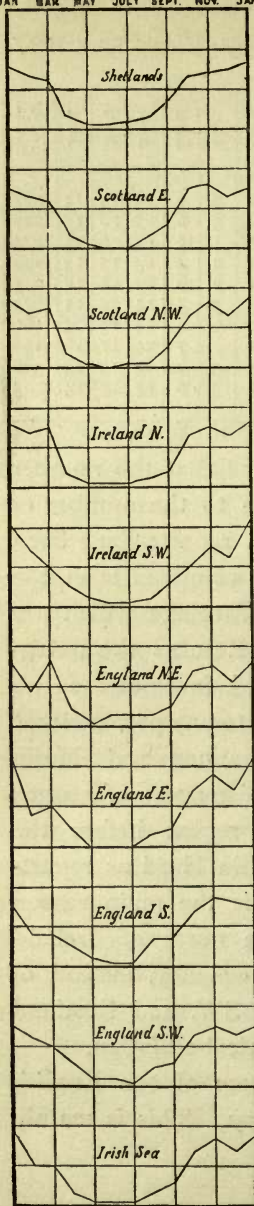


FIG. 46.—Monthly Storm frequency on various parts of the coasts of the United Kingdom.

owing to the extreme storminess of Scilly.

The eastern part of the Channel and the east coast of England are the least storm-swept parts of our shores. This is naturally to be expected, as the force of the storms is broken by their passage over the land.

If we now exhibit graphically the monthly march of storm frequency in the ten districts (fig. 46), we find that in every case the summer is all but absolutely free from storms. In almost every district, also, November is stormier than December.

The most remarkable portion of the diagram is that representing the spring time. It will be seen that in most of the districts there is a distinct maximum of storminess in March, which is especially prominent in the north-east of England, while it is entirely absent in the south-west of Ireland, and very nearly so in the Irish Sea and the south-west of England.

All these results require further study to explain them fully, but as far as they go they are very interesting and of much practical importance.

In the matter of periodicity of storms there is a belief, which is very widespread, that equinoctial gales are a phenomenon recurring with almost perfect regularity. The remark is often made that it would be well for those proposing to take a voyage to wait until the equinoctial gales were over. In order to test the foundation of this general belief, I made a catalogue of all the serious storms which have been reported in the British Isles since Easter 1870, and communicated the results to the Royal Meteorological Society in 1884.¹ I have recently extended the list up to Easter 1887, so that the figures refer to a period of seventeen complete years.

The mode of inquiry has been to take fifteen-day periods (that is, to take seven days on each side of the equinox), and to divide the year into equal intervals of this length. Of course, we have twenty-four such spaces, with a remainder of five days, which have been omitted at the beginning of July, that being the calmest part of the year.

The dates of the several storms are given in Table I. (p. 132), and curves are also given (fig. 47, p. 130) showing the march of frequency in the fifteen-day period, both for the crude and the smoothed figures.

¹ *Quarterly Journal of the Royal Meteorological Society*, vol. x. p. 236.

These show that the storms are all but exclusively confined to the winter half-year.

A glance at Table I. (p. 132) will show how for a certain interval the stream of storm depressions sets over us and then for a time takes another path, leaving us at rest. In some years we have as many as four or five storms in a fifteen-day period, and in others we

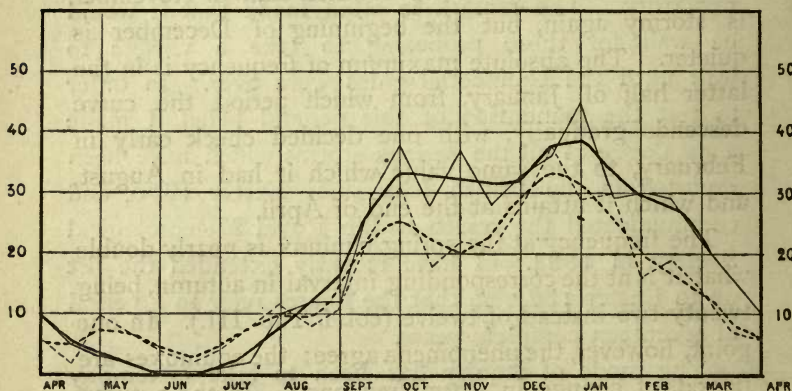


FIG. 47.—Frequency of Storms in fifteen-day periods, according to Scott and Prince.

In this diagram (representing Table III., p. 135) the vertical rules correspond approximately to the middle days of the respective months.

The faint full line corresponds to the original figures	} Scott.
The dark „ „ „ smoothed „	
The faint dotted „ „ „ original „	} Prince.
The dark „ „ „ smoothed „	

have none or only one. This happens even in the latter half of January, the stormiest period of all.

The diagram shows that there is no strongly marked maximum of frequency at either equinox, but there are indications of periodicity which are very interesting.

Leaving the summer alone, as not worth notice, the frequency remains practically constant from the middle of August until the autumn equinox is past. The curve then rises rapidly, the value doubling itself and trebling itself in the two succeeding intervals. We then find a falling off at the time of the Martinmas summer in the first half of November, the latter half of November is stormy again, but the beginning of December is quieter. The absolute maximum of frequency is in the latter half of January, from which period the curve descends gradually, with one decided check early in February, to the same value which it had in August, and which it attains at the end of April.

The frequency at the spring equinox is nearly double what it is at the corresponding interval in autumn, being twenty-two instead of twelve (col. i. Tab. III.). In one point, however, the phenomena agree: the equinoxes are periods of change in storm frequency. In the autumn this rises from twelve to twenty-nine as soon as the equinox is passed; in the spring it falls from twenty-nine to twenty-two as the equinox approaches.

Accordingly, persons who wait till the autumn equinox is over materially increase their chance of falling in with a storm, but in the spring it would apparently be wise to wait till April was well advanced if you wished to have calm weather at sea.

If we look to see what evidence of the recurrence of storms for particular short periods is discoverable in our data, we find that the days most frequently so

TABLE I.—DATES OF STORMS (BEGINNING THE YEAR WITH APRIL 13TH).

Month.	1870-1.	1871-2.	1872-3.	1873-4.	1874-5.	1875-6.	1876-7.	1877-8.	1878-9.	1879-80.	1880-1.	1881-2.	1882-3.	1883-4.	1884-5.	1885-6.	1886-7.
April	...	...	21	...	...	...	14	16	16, 21	14	18, 21	...	...	17, 30	25	...	...
May	12	...	4	...	...	...	...	...	10	...	...	16	...	...	2, 7	...	17
June	...	...	...	...	...	...	...	1, 5	...	...	...	...	...	...	...	...	...
July	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Aug.	...	24	...	28	...	...	2, 31	25	30	{ 25, 27, 28 }	...	26	23	...	...	10	...
Sept.	4, 9	27	24, 27	...	21	24, 27	30	13	15, 18	3, 22	14	...	2	1, 26	{ 7, 27, 30 }	{ 10, 12, 10, 30 }	9, 27
Oct.	{ 12, 15, 18, 23 }	{ 1, 21, 27, 28 }	10, 23, 29	6, 10, 20, 22	3, 6, 9, 17, 21	6, 21	{ 11, 16, 29 }	{ 10, 13, 15, 20, 29, 31 }	{ 7, 10, 22, 24, 28, 30 }	20	{ 5, 7, 22, 27 }	{ 14, 19, 21, 22, 31 }	{ 1, 19, 24, 28 }	4, 15, 17, 25	10, 26, 28	{ 1, 2, 6, 8, 12, 27, 31 }	9, 15
Nov.	10, 22	20	{ 1, 6, 10, 23, 25 }	{ 1, 10, 22, 27, 29 }	29	13, 19	{ 3, 5, 10, 20, 26 }	{ 10, 11, 14, 15, 25, 28 }	{ 8, 10, 12, 16 }	11, 20	{ 9, 13, 16, 18, 20, 22, 25, 26, 28 }	{ 9, 13, 16, 19, 20, 22, 24, 27, 30 }	{ 8, 14, 16, 20, 28 }	24, 27	4, 8, 21	26, 28	3, 6, 29
Dec.	23, 24	{ 18, 20, 28 }	{ 8, 16, 20, 22, 24, 27 }	16, 21, 29	4, 8, 11, 16	21, 24	{ 3, 5, 10, 20, 26 }	{ 6, 11, 25 }	31	{ 4, 23, 27, 28, 30 }	10, 12, 18	{ 6, 18, 20, 24 }	{ 2, 5, 7, 28 }	{ 12, 14, 16 }	{ 3, 4, 7, 10, 14, 19, 20 }	{ 1, 4, 27 }	8, 22, 26
Jan.	{ 6, 10, 15, 16, 31 }	{ 1, 3, 4, 5, 13, 17, 24, 25, 31 }	{ 1, 4, 6, 8, 13, 18, 22, 26 }	{ 1, 4, 8, 18, 20, 26 }	{ 1, 5, 5, 15, 19, 24, 26 }	6, 18, 19, 24	{ 4, 7, 8, 19, 23, 25, 28, 30 }	{ 1, 21, 23, 25 }	{ 7, 10, 17, 19 }	1	18	2, 6, 8	{ 2, 10, 14, 19, 24, 25, 27, 28 }	23, 26, 27	{ 8, 11, 14, 28, 31 }	{ 5, 7, 13, 19, 29 }	3, 11, 26, 28
Feb.	{ 5, 10, 12, 21, 23 }	{ 4, 3, 12 }	2	{ 10, 26, 28 }	{ 24, 26 }	{ 3, 15, 19, 23, 26 }	{ 2, 19, 22, 26 }	17	...	{ 6, 9, 13, 15, 16, 19, 26 }	7, 10, 13	{ 1, 6, 9, 12, 14, 17 }	{ 1, 6, 9, 12, 14, 17 }	1, 10, 16	6, 8, 21, 26	...	3, 23
March	{ 6, 7, 9, 12, 15 }	{ 18, 28 }	10, 15	{ 19, 27, 29 }	{ 9, 11 }	{ 3, 6, 9, 12, 15, 18 }	{ 7, 12, 14, 25 }	{ 6, 7, 24, 29 }	{ 4, 5, 12, 28 }	1, 2	{ 3, 18, 23 }	{ 9, 22, 26 }	{ 6, 8, 17, 22, 29 }	4, 20	{ 17, 18, 20, 26 }	{ 1, 9, 27, 30, 31 }	28
April	...	3	...	{ 1, 2, 12 }	...	10	...	7	...	...	2	...	...	...	5	{ 2, 3, 7 }	...
Totals	26	25	29	28	22	24	32	32	25	27	25	27	36	21	33	30	18

distinguished in Table II. are Jan. 1 and 19, on both of which storms occurred six times in the seventeen years.

TABLE II.—DIURNAL FREQUENCY.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	6	3	2	1	...	1	1	...	1	3	3	1
2	2	2	1	3	1	...	...	1	1	1	...	1
3	3	3	2	2	...	...	...	...	1	2	1	2
4	4	...	2	...	1	...	...	...	1	1	2	4
5	2	1	1	1	...	1	...	...	...	1	1	2
6	4	3	4	...	...	...	...	...	...	4	2	2
7	3	1	3	2	1	...	...	...	1	2	...	2
8	4	1	1	...	...	...	...	...	...	1	3	3
9	...	2	5	...	...	...	...	...	2	2	1	...
10	3	4	1	1	...	...	...	1	1	4	5	3
11	2	...	1	...	...	...	...	...	...	1	3	2
12	...	3	4	1	1	...	...	...	1	2	1	2
13	3	3	...	...	...	...	...	...	1	1	2	...
14	4	1	1	2	...	...	...	...	1	1	2	2
15	2	2	3	...	...	...	...	...	1	4	2	...
16	1	3	...	2	1	...	...	...	...	1	4	4
17	2	2	2	1	1	...	...	...	...	2	...	...
18	5	1	4	1	...	...	...	...	2	1	1	3
19	6	3	1	...	1	...	...	...	...	2	2	1
20	1	...	2	...	...	...	1	...	...	3	5	5
21	1	2	...	3	...	...	...	...	1	4	1	2
22	1	1	2	...	...	...	...	...	1	4	4	3
23	3	3	1	...	...	...	...	1	...	2	2	1
24	4	1	1	...	...	...	...	1	2	2	2	4
25	4	...	...	1	...	...	...	2	...	1	3	1
26	5	5	1	...	...	...	...	1	1	1	2	2
27	3	...	2	...	...	1	...	2	4	3	3	3
28	4	2	2	...	...	...	...	2	...	4	4	2
29	...	...	3	...	...	...	...	...	...	4	2	1
30	2	...	1	1	...	...	...	1	3	1	2	1
31	3	...	1	...	...	...	...	1	...	3	...	1
	87	52	54	22	7	3	2	13	26	68	65	60

Seven days—Jan. 18 and 26, Feb. 26, March 9, Nov. 10 and 20, and Dec. 20—show five each, and twenty-five days show four.

The stormiest period of all is the six days succeeding Jan. 22, the figures for which are 3, 4, 4, 5, 3, 4.

The date of the Battle of Trafalgar, Oct. 21, is marked by two fours, but no other storm of historic fame is specially noticeable.

It is of interest to find that the results above given for storm periodicity have recently been confirmed in a very satisfactory manner by the figures for storm periodicity in Sussex published by Mr. C. L. Prince in a recent number of the *Quarterly Journal of the Royal Meteorological Society* (vol. xiii. p. 79). Mr. Prince has carried on meteorological observations for nearly half a century, first at Uckfield, and latterly at his observatory on Crowborough Beacon, and the paper to which reference has been made gives the dates of all storms recorded by him during the forty years 1846 to 1885 inclusive.

As Mr. Prince's data refer to one district only, while mine refer to the entire United Kingdom, the total number of gales recorded by him in forty years is only 371, while the larger area for seventeen years yields 459. The distribution of gales in the two investigations agrees very closely, as will be seen by comparing the figures in cols. ii. and iv. of Table III. (p. 135) with those in cols. i. and iii.

There is one remarkable exception—that Mr. Prince finds a greater frequency of storms in May than my figures show.

His results are shown graphically in fig. 47 (p. 130) by the dotted lines.

Mr. Prince concludes his paper with the very confident statement: 'We may now assert that gales at the period of the equinoxes are more the exception than the rule.'

TABLE III.—FIFTEEN-DAY PERIODS.

PERIOD.	i.	ii.	iii.	iv.
April 12 to April 27	10	6	10.25	5.25
April 28 „ May 12	5	2	5.75	5.
May 13 „ May 27	3	10	3.25	7.25
May 28 „ June 11	2	7	1.75	7.
June 12 „ June 26	0	4	0.5	4.25
July 2 „ July 16	0	2	0.25	3.
July 17 „ July 31	1	4	1.	4.5
Aug. 1 „ Aug. 15	2	8	3.75	8.
Aug. 16 „ Aug. 30	10	12	8.	10.
Aug. 31 „ Sept. 14	12	8	11.5	9.75
Sept. 15 „ Sept. 29	12	11	16.25	13.25
Sept. 30 „ Oct. 14	29	23	27.	22.
Oct. 15 „ Oct. 29	38	31	33.25	25.75
Oct. 30 „ Nov. 13	28	18	32.75	22.25
Nov. 14 „ Nov. 28	37	22	32.25	20.75
Nov. 29 „ Dec. 13	28	21	31.5	23.
Dec. 14 „ Dec. 28	33	28	32.25	28.75
Dec. 29 „ Jan. 12	36	38	37.5	33.25
Jan. 13 „ Jan. 27	45	29	38.25	31.5
Jan. 28 „ Feb. 11	29	30	33.25	26.25
Feb. 12 „ Feb. 26	30	16	29.5	20.25
Feb. 27 „ Mar. 13	29	19	27.5	17.
Mar. 14 „ Mar. 28	22	14	22.25	13.5
Mar. 29 „ April 12	16	7	16.	8.5

- i. Numbers according to R. H. Scott.
 ii. Ditto C. L. Prince.
 iii. The figures in column i. smoothed by the formula

$$B = \frac{a + 2b + c}{4}.$$

- iv. Ditto ii. ditto.

It may be said that this is not the first time that the notion that equinoctial gales are felt in northern Europe has been combated. Professor Dove, in the

last edition of his 'Gesetz der Stürme' (1873), says at p. 197, when speaking of storms arising outside the Trade-Wind Zone :

'In western Europe these storms are rare, and probably are never experienced in summer; we must now examine into the reason of this, and must take care to remember the changes in atmospherical conditions which occur in spring and autumn. Lucretius calls these epochs "the wartime of the year," and in fact an Italian may well speak of equinoctial storms. Such an expression, however, sounds strange from the mouth of a German, for we cannot help thinking that he puts the equinox at Christmas, and forgets that September is the most usual month for the occurrence of that phenomenon.'

In conclusion, it may be said that in the *Annalen der Hydrographie und Maritimen Meteorologie* for 1884, at p. 625, a paper appeared which showed that for the north coast of Germany the periods of the equinoxes were not remarkably stormy; and as for the Adriatic, a paper by Dr. Robert Müller in *Mittheilungen aus dem Gebiete des Seewesens* for 1887, at p. 144, shows that, though there exists at Pola a slightly marked maximum of frequency at the time of the spring equinox, nothing of the kind is traceable at the autumn equinox.

CHAPTER IX.

STORM WARNINGS.

STORM WARNINGS may be considered as the most immediate practical application of weather knowledge, and in fact it was the possibility of issuing such intelligence which gave the first impetus to the development of Weather Telegraphy. Although this branch of the subject has not yet been reduced to such strict rules of procedure as are demanded by the requirements of an exact science like Astronomy, meteorologists can at all events lay claim to having established some principles which are sufficient, in many cases, to throw valuable light on the conditions which may be expected to result from existing circumstances, and so to some extent to lift the veil which shrouds the future from our eyes.

The first suggestion of the electric telegraph as a method of conveying intelligence of storms from one place to another is apparently due to Mr. Redfield in America, who shares with our own countryman, Sir W. Reid, the honour of having reduced the Law of Storms to a science. Redfield's paper is in the *American Journal of Science and Art* for 1847, and

this was followed in this country, after a brief interval, by a communication from a man still living amongst us, Mr. John Ball, F.R.S., as will be seen below.

The subject was taken up in a tentative way in the United States between the years 1850 and 1860, but further operations in this direction were brought to a standstill by the war in 1861.

On this side of the Atlantic the credit of taking the initiative is due to Leverrier, the famous director of the Paris Observatory, who, as early as on February 17, 1855, received the Emperor's sanction for the creation of an extensive organisation destined to distribute intelligence of weather over the countries embraced by it. The possibility of rendering such an organisation really useful had been previously shown by the study of the Balaclava storm of November 14, 1854, which had wrought immense damage to the allied fleets in the Black Sea, and by whose effects hardly a country in southern Europe had been left unscathed. It was evident, from a mere cursory study of the facts of this storm, especially of its rate of progress, that timely notice of its approach might have been issued from the coasts which were first visited to those which subsequently felt its effects.

The plan gradually assumed a definite form, and in the spring of 1860 M. Leverrier addressed a letter to Sir George Airy, inviting the co-operation of this country in his scheme. This letter contains certain expressions which have such an important bearing on

the subsequent history of storm warnings that they are worth translation and quotation. They are as follows:

‘The ultimate result of the organisation which we are establishing should be to announce a storm as soon as it appears at any point in Europe, to follow it on its course by means of the telegraph, and to give timely notice of it to the coasts which it may reach.’

We shall presently learn to what extent this programme has been carried out, and to what extent it has been possible to go beyond it.

In this country the idea of storm warnings had been broached before 1860, for at the meeting of the British Association at Swansea in 1848, Mr. John Ball, F.R.S., read a paper entitled ‘On rendering the Electric Telegraph subservient to Meteorological Research.’ This communication is so interesting and brief, that we reproduce it in a note.¹ Eleven years subsequently, at

¹ ‘What is popularly termed the weather is a general expression for the physical condition of the atmosphere with reference to heat, pressure, moisture, and the velocity and direction of its motion. Two classes of causes determine these conditions at any given point of the earth’s surface. The first class may, for short periods of time, be considered as constants, depending on the position of the point of observation on the globe, and the physical conformation of the adjoining district. The second class, upon which the proverbial uncertainty of the weather depends, arises from the influence exerted by each portion of the atmosphere upon those surrounding it, by virtue of which a disturbance of equilibrium at any one point is rapidly propagated in all directions. In common language, this is expressed by saying that the direction of the wind is at once the cause and the indication of changes of the weather. However far we may be from a general solution of the problem of atmospheric disturbances, meteorologists have made considerable progress in tracing the connection between successive states of the weather, owing to the mutual influence of contiguous portions of the atmosphere. These

the Aberdeen meeting of the same Association in 1859, a formal resolution was adopted in favour of the organisation of such a system. A month after the meeting the loss of the *Royal Charter* on the coast of Anglesea arrested universal attention, and as there seemed, at first sight, a chance that that ship might possibly have been warned of her danger, the hasty conclusion was drawn that no storm could ever come on without giving timely indication of its own approach. Subsequent experience soon proved how very unsafe such a generalisation was.

Early in 1861 the first tentative warnings were sent out, and by the beginning of 1862 Admiral FitzRoy's

cases have been studied *à posteriori*, comparing the known results with observations extending over considerable areas. Now that we have the means of receiving information in an indefinitely short space of time by the Electric Telegraph, these problems, under favourable circumstances, may be studied *à priori*. In London we may receive instantaneous intelligence of the condition of the atmosphere, as to the five above-mentioned elements, from nearly all the extremities of Great Britain. With a delay of about four hours we can have similar intelligence from the western part of Ireland, and with a still shorter delay, our communications may extend to the centre of France, the banks of the Rhine, and even to the frontiers of Hungary and Poland.

'I do not pretend to say that with such elements for calculation we should at once be enabled to predict changes in the weather with absolute certainty. It would require some time to eliminate the action of accidental and local causes at particular stations; but there is no reason to doubt that in a short time the determinations thus arrived at would possess a high degree of probability. The ordinary rate at which atmospherical disturbances are propagated does not seem to exceed twenty miles per hour; so that, with a circle of stations extending about five hundred miles in each direction, we should in almost all cases be enabled to calculate on the state of the weather for twenty-four hours in advance.'—*Report British Association*, 1848 ('Notices and Abstracts,' p. 12).

system was definitely established. The principles on which our present warning system is based are mainly the same as the principles of that devised by the Admiral, but exhibit some contrasts to them.

Admiral FitzRoy, when he issued a signal, intended by it to imply that the storm of which he gave warning would be likely to occur within the next seventy-two hours. He therefore had the signals kept up until the evening of the day on which they were hoisted, and then lowered, while by the present system they are not lowered until all danger of the gale appears to be past. It is evident from this that if, as often happens, threatening symptoms disappeared without the actual occurrence of a gale, Admiral FitzRoy had no means of announcing to the ports, on the day after the issue of a warning, the fact of the improvement in the weather prospects. This arose from the fact that once his signal had been lowered there was no public indication that it had even been hoisted at all, and yet the warning had been intended to cover three whole days. By the present system the fact that no signal is exhibited is, to a certain extent, a proof that no danger is apprehended at the Office in London.

It is hardly necessary to describe the signals, as their appearance is familiar to all who have been at seaside places, but for the sake of those who may not have been on the coast in winter, at which season the signals are most frequently visible, the following official explanation of their meaning may be reproduced.

TELEGRAPHIC WEATHER INTELLIGENCE.

The Meteorological Office issues (free of charge) to ports and fishing stations approved of by the Board of Trade, notices of atmospherical disturbances on or near the coasts of the British Islands.

Signals.

The fact that such a notice has been received at any station is made known by hoisting a **Cone**, which is three feet high and three feet wide at base, and appears as a triangle when hoisted.

Southerly Gale.

The **Cone** *point downwards* means that gales, or strong winds, are probable, at first from the Southward (from S.E. round by S. to N.W.)

Should it appear likely that a gale beginning from between N. and N.W. is likely to *veer* towards N. or N.E., the *North* Cone is hoisted in preference to the *South* Cone.

Northerly Gale.

The **Cone** *point upwards* means that gales, or strong winds, are probable, at first from the Northward (from N.W. round by N. to S.E.)

Should it appear likely that a gale beginning from between E. and S.E. is likely to *veer* towards S. or S.W., the *South* Cone is hoisted in preference to the *North* Cone.

Sudden Shifts of Wind.

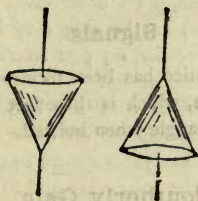
It must be remembered, that a Southerly wind is much more likely to *veer* quickly to a point North of West than a Northerly wind is to *veer* to a point South of East, and that a gale from East is more likely to *back* to the *Northward* than to *veer* to the *Southward*.

Accordingly, when the South Cone is hoisted and the anchorage or harbour is exposed to the North-West, it is advisable to bear in mind that a gale commencing at South-West may shift suddenly to North-West.

CAUTIONARY SIGNALS.

Day Signals.

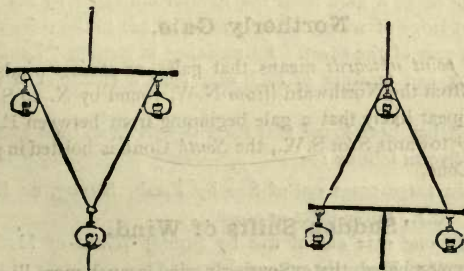
SOUTH CONE. NORTH CONE.



Gale probably
from the
Southward.

Gale probably
from the
Northward.

Night Signals (instead of the above) Lights in triangle.



Three lanterns and one yard, 4 ft. long, will be sufficient.

FIG. 48.

On Hoisting the Signals.

The signal is to be kept flying until dusk, and then lowered to avoid unnecessary wear and tear, but to be hoisted again at daylight next morning ; and so until the end of 48 hours from the time at which the message was issued from London, unless orders to lower the signal are received previously. The time of issue is always marked on the telegram.

At dusk, whenever a signal ought to be flying if it were daylight, a night signal may be hoisted in place of the Cone, consisting of three lanterns hung on a triangular frame, point downwards (for South Cone), or point upwards (for North Cone) as the case may be. They should be kept burning until late in the evening, say 9 or 10 o'clock, or longer if the local authorities should think it important.

These signals may be made with any lanterns, showing white or any colour, but the lanterns should be *all alike*. Red is best. Lamps are better than candles. The halyards should be of good rope, and should be protected from chafing. The lanterns should hang at least three feet apart.

Meaning of Signal.

The hoisting of any of these signals is intended as a sign that in the neighbourhood (say, within a distance of 50 miles) of the place where the signal is hoisted, there is an atmospherical disturbance in existence which will *probably* cause a gale from the quarter indicated by the signal used, and the knowledge of which is likely to be of use to the sailors and fishermen on that part of the coast. Its meaning is simply, "Look out ! It is probable that bad weather of such and such a character is approaching you."

Hitherto it has been found that these signals have been justified in four cases out of five as follows :—

- (1.) In three cases out of five by Fresh, Strong, or Heavy Gales
(*i.e.*, Force eight or more).
- (2.) In one case out of five by Strong Winds or Moderate Gales
(*i.e.*, Force six or seven).

In every case some of the principal reasons which have led to the hoisting of the signal are briefly explained in the telegram, *which should always be kept posted up for public inspection while the signal is flying.*

The simplicity of the idea of using a cone, which

must necessarily show the same shape as a triangle, no matter how it is blown about by the wind, is the great merit of FitzRoy's plan, as the sailor need not burthen his memory with a complex code of signals. In fact, when the Meteorological Office in 1868 made an attempt to introduce a more complex apparatus, like a railway semaphore, in order to convey intelligence to ships in the offing, the experiment fell perfectly flat, owing to the difficulty of instructing our coasting seamen, for whose benefit storm warnings are originally intended, in the use of a totally novel system.

The question of signals is not an easy one to set finally at rest. There is no doubt that the information conveyed by them would be infinitely more valuable if they could be shown from headlands which shipping usually make, such as the Lizard, than if they were simply exhibited in harbours. Here then we see the necessity for a special signal code. By our present system we can only give a limited number of possible signals, so that we cannot convey detailed information to ships at any distance from the shore; say, even riding at anchor in the Downs.

Our system is to hoist the signal as an indication that some information of a certain kind has been sent to the signal station, which it is of importance to the seaman to know: but he must land and read the telegram himself if he wants to learn more precisely what the facts are. We are as yet a long way off from the condition which may be described as the acme of

weather-signalling, and which has often been suggested, that of having a weather signal book containing charts of different types of weather, much like the illustrations in these pages, duly numbered, so that by simply hoisting a number on the signal staff, we could tell the seaman to what page in the book he had to turn, and what weather he had to expect. Thus, such a chart as that for November 29, 1874 (fig. 2), might be described as No. 371, and so on. It will, however, be many a long year before our knowledge of weather will justify our issuing such a collection of typical weather maps as would be likely to be of service for such a purpose, but possibly in the future something of this kind may be done.

If it be asked what the real practice of storm warnings is at present, the reply is that it is a moderate advance on Leverrier's anticipations in 1860 (p. 139). It will appear from the previous pages that we have some sort of knowledge of the circumstances under which the various types of storms approach the different parts of our coasts, but these are not sufficient to tell us in every case when a storm is imminent.

Some conditions give us more warning than others, but the cases in which we have definite premonitions are not of very frequent occurrence, and in general it is not until the storm is quite close at hand, and the barometer has begun to fall briskly at the outposts, that we feel ourselves justified in issuing a definite warning. The appearance of one of the small secondary

depressions, however, not very unfrequently precedes that of a more serious storm ; accordingly, if we notice one of these lesser disturbances, we are at once put on our guard.

A rapid and unexpected rise of the barometer is often the precursor of a coming depression, so that whenever we see a sudden rise we may expect an equally sudden fall, and must be on the look-out for the slightest tendency of pressure to give way.

It should, however, be remembered that, as regards barometrical indications, we are guided not only by the actual fall of the mercurial column on a certain line of our own coasts, but also by the behaviour of the barometer at far distant Continental stations. Thus, in the case of the storm already so often quoted, November 29, 1874, a warning had been issued to the coasts at 3.30 P.M. on the 28th, when the most alarming sign was not so much the fall of the barometer at our south-western stations, taken by itself, as the fact that this was accompanied by a slight rise, of 0.01 inch, since 8 A.M. at Rochefort, readings in the south-west of France being already seven-tenths of an inch higher than in the south of Ireland. This showed that pressure was banking up to the southward, and that gradients were consequently becoming steeper along the Channel. If, when the barometer falls at our south-western stations, the fall affects those in the south of France, we know that we have less to fear from Westerly winds, as the tendency of such a change is to reduce the gradients

for winds from that point, while a rise of pressure over France when it is already relatively high there, puts us at once on our guard for a blow from the Westward.

Similar reasoning will apply to barometrical indications in other parts, but the changes in direction of the wind are of almost equal value to them, and in some respects of even higher importance, as giving earlier intimation.

The proverbial danger of a backing wind has already been alluded to, p. 78; this, however, is chiefly true as concerns the 'backing' of the wind from NW. to SW. and S., which indicates the approach of a fresh disturbance, for it has been explained that if one cyclonic system is following another in quick succession, as the wind on the southern side of each runs gradually from SE. through S. and W. to NW., the approach of the second depression must cause the vane to shift back from NW. towards SE. This backing is almost the most dangerous sign of all.

It has, however, been stated already that it is not safe to depend on the observations from our western stations as to the direction and force of the wind, owing to the hilly nature of the coasts, so that we cannot implicitly trust the reports on this subject which we receive.

Another very important sign as regards the wind, is the indraught of air towards the storm area. This is perfectly intelligible on the supposition that the air really flows in towards the centre and rises there. On

the approach of a cyclone to the west coast of Ireland, we frequently find the winds South-westerly on the west coast of France, as on November 28, 1874 (p. 90), while we can hardly say that the barometer on that coast, at such a distance from the centre of the disturbance, had yet felt its influence.

The reports of sea disturbance are even more uncertain guides to us than the observations of wind, as is explained in Chapter I., p. 11.

Temperature is also a very useful aid in gaining a knowledge of coming disturbance, for it will be remembered how the rise of the thermometer in front of a storm is a marked characteristic of areas of low pressure, but the indications of temperature have, for various reasons, not yet been reduced to strict rules like those of the barometer.

We know, however, that a great contrast of temperature between adjacent stations, being an indication of serious atmospherical disturbance, is the precursor or concomitant of a serious storm, so that if we find a great difference between the reports of temperature, we are at once warned of approaching disturbance. Some striking instances of this fact may be cited. On November 13, 1875, at 8 A.M., the thermometric report from Scilly was 57° , and from Wick 21° . The resulting difference is 36° . The gale of Sunday, November 14, with its accompanying high tide and consequent inundations on the south coast and in London, was long remembered by the residents in that part of

England. Again, on December 8, 1886, an unusually severe storm crossed the north of Ireland and England. This had been preceded by remarkable unsteadiness of temperature. On the 4th of the month the change in 24 hours had been 21° at Hurst Castle and Dungeness, 18° in London, and 17° at Loughborough. On the 6th the change had been 22° at Loughborough, 21° in London, 20° at Oxford, and 19° at Cambridge and Dungeness. Accordingly, the atmosphere had been in a state of disturbed equilibrium for four days before the storm.

Besides all the symptoms of the approach of a storm which have been enumerated, there are the innumerable local signs which enable the fisherman and shepherd, not to speak of the inferior animals, to judge of coming bad weather. Among all these, almost the most important are the character and motion of the upper clouds. Another great sign is the clearness of the atmosphere, the unusual visibility of distant objects, which is well known as a sign of a coming gale.

It must always be remembered that, in order to issue perfectly correct storm warnings, we should require to know the size, shape, position, and motion, in direction and rate, of an advancing depression, and also whether it is becoming deeper or the contrary, and that *there is not one of these conditions of which we have a really sufficient knowledge at present*, while of most of them we can have no knowledge at all till the storm has burst upon us. The problem which is put before the

Meteorological Office daily, is similar to one which astronomers would at once recognise as impossible of solution, and that is to determine the elements of a comet's path from a single observation taken, say, in a brief clear interval on a cloudy night. The first glimpse we get of a storm must suffice for us to issue our warnings.

It is therefore evident that for our own exposed western and northern coasts we can but rarely issue timely warnings, but fortunately these iron-bound shores are not frequented by an amount of coasting craft at all to be compared with that navigating the comparatively calmer waters of the two Channels and the North Sea.

The results of the warnings *to our own coasts* have been printed in the Reports of the Office for several years back. The following are the figures for the year 1885, being the last which have been published :—

RETURN OF THE RESULT OF THE COMPARISON BETWEEN THE WARNINGS ISSUED
AND THE WEATHER EXPERIENCED IN 1885.

Coasts.	Total Number of Orders to hoist and Re-petitions.	Warnings justified by Subsequent Gales. Force 8 and upwards.	Warnings justified by Winds. Force 6 and 7.	Warnings not justified by Subsequent Weather.	Warnings late. Force 9 reached at Two Stations before Issue.	Warnings partially reached at One Station before Issue.	Warnings in Error owing to Telegraphic Mistakes.	Storms for which no Warning was issued.
Ireland, South.	74	47	16	10	...	1	...	Jan. 28, Feb. 6, April 5.
Ireland, East.	79	32	27	20	...	...	...	April 5.
Scotland, East.	65	42	13	9	...	1	...	April 20 ¹ , Sept. 30, Oct. 1 ¹ .
Scotland, West.	56	29	14	12	...	1	...	...
England, North-west.	78	39	18	19	1	1	...	Jan. 28 ³ .
England, West.	65	41	10	12	...	2	...	Oct. 4.
England, South.	79	46	18	15	...	...	...	Feb. 8 ³ , Aug. 12 ³ , Oct. 4.
England, South-east.	36	24	6	6	...	...	...	...
England, East.	59	27	20	12	...	...	...	...
Totals.	591	327	142	115	1	6	...	
Percentages.	...	55.3	24.0	19.5	0.2	1.0	...	

¹ These gales were not felt south of Aberdeen.

² Warnings too late to be of practical use.

³ Warnings issued to Devon and Cornwall; gale extended up Channel.

If these figures be compared with those for the preceding eight years, we see that the results in percentages are fairly constant.

YEARS.	Warnings justified			Warnings not justified by Subsequent Weather.
	By Subsequent Gales.	By Subsequent Strong Winds.	Total Success.	
1877	53.3	25.9	79.2	16.4
1878	56.7	20.8	77.5	17.9
1879	50.5	25.1	75.6	20.6
1880	58.2	24.6	82.8	13.3
1881	58.6	23.3	81.9	14.8
1882	61.4	21.1	82.5	14.9
1883	56.2	21.6	77.8	20.8
1884	66.4	20.0	86.4	12.1
1885	55.3	24.0	79.3	19.5
Average	57.4	22.9	80.3	19.7

Accordingly, it appears that more than half the signals of approaching storms (force upwards of 8, Beaufort scale, 'a fresh gale') were fully justified, and the same is the case for four out of five signals of approaching strong winds (force upwards of 6, Beaufort scale, 'a strong breeze').

It is therefore evident that the system of storm warnings renders it possible to give useful intelligence to the coasts, but it need hardly be said that the system for these islands is rather of the 'from hand to mouth' type, and that our warnings would be far more useful if they could be issued sooner, so as to render it possible for captains to get intimation of a coming gale before leaving port. This, however, can hardly be hoped for in the present state of weather telegraphy, and a few

instances will suffice to show some of the principal causes of failure of warnings, in addition to those arising from the imperfections of our arrangements, which have been already described.

We shall commence with a case in which even a practised seaman's experience was at fault, so that we can hardly blame our telegraphic reporters, who are mostly landmen, for their failure to notice, from the appearance of the sky and sea, that a storm was imminent. Nearly fifteen years ago, on November 22, 1872, there was a tremendous gale in the Channel, when the *Royal Adelaide* was lost on Chesil Bank. On that day at noon the telegraphic reports had shown an apparent improvement on the weather of the previous day, so that the signals then flying were lowered on the south coast. At night the storm came on, and of course the comments on the Office were not favourable. On this day one of our best sea-observers, the late Captain Thomas Donkin, of the *Inverness* (one of the three ships that rode out the Madras cyclone of May 2, 1872), was out in the gale, and was blown back by it, hove to, from the Lizard to the Casquets, off Alderney. We wrote to him as soon as we heard that he was safe at anchor at Portland, to ask him whether he, being at sea, had anticipated the storm from the look of the sky and sea; and his answer was: 'With respect to the weather on November 22, I may say that at noon I was standing in towards the land, between Falmouth and Plymouth, and a pilot cutter came alongside, and if I had had the

least apprehension of such a gale as followed being near at hand, I should have taken a pilot and gone into Plymouth. The appearance of the weather at the time was fine, though the glass was falling, though not low at the time for SW. wind and unsettled weather.'

In this case, therefore, the signals, once hoisted, had been lowered too soon.

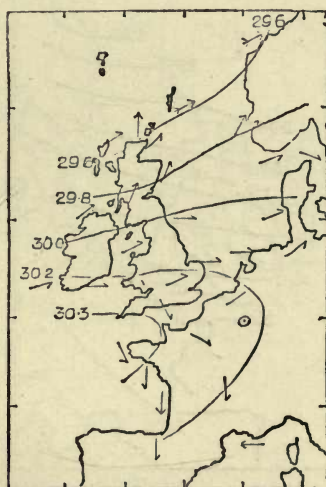


FIG. 49.—October 20, 1874; 8 A.M. Depression approaching coast of Norway.

The next case, which will be illustrated by charts, affords specimens of a double failure of warning. In the first instance the signals had been hoisted on the north-west coasts on the morning of the 20th, and had been lowered again in the afternoon, while subsequently they were hoisted unnecessarily and had to be lowered.

The gale is that of October 21, 1874, which has already been noticed, p. 72.

Taking the first chart (fig. 49, p. 155) for 8 A.M. October 20, we find pressure highest over the entrance of the Channel, and lowest in the far north, where SW. gales are reported. These gales, with a falling

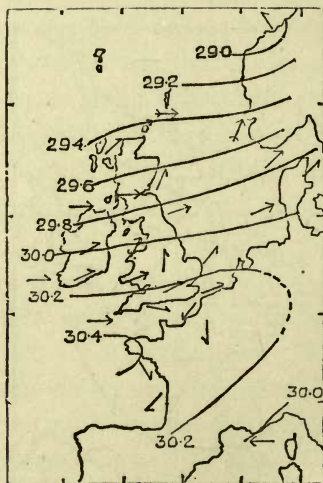


FIG. 50.—October 20, 1874; 6 P.M. Depression off Christiansund.

barometer in Scotland, caused some alarm, but this was allayed by our finding conditions unchanged at 2 P.M. By 6 P.M., however (fig. 50), the depression existing in the north had advanced to the coast of Norway, where the barometer had fallen 0.6 inch, but the signs of danger to ourselves were the bend southwards of the isobar of 29.4 round the Butt of Lewis, and the backing

of the wind, though still light in force, to South-west at Stornoway and over the Moray Firth, and, though last not least, the steady rise of the barometer at the entrance of the Channel.

During the night the storm came on, and at 8 A.M. October 21, its centre lay half-way between Peterhead and the Shetlands (fig. 51), while a terrific Westerly

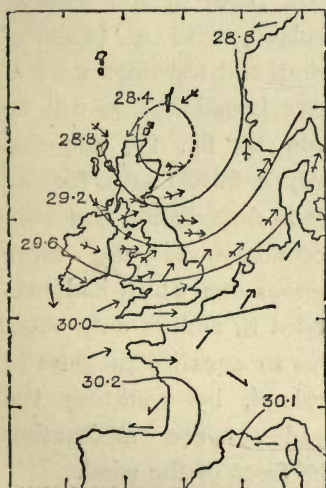


FIG. 51.—October 21, 1874; 8 A.M.
New depression off north of
Scotland.

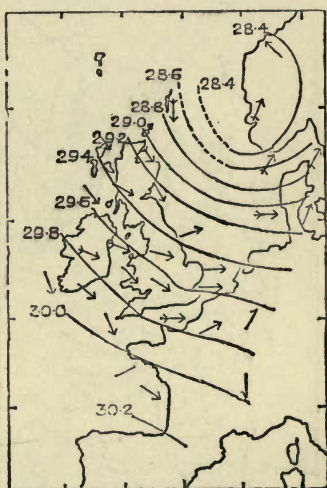


FIG. 52.—October 21, 1874; 6 P.M.
Depression has advanced to the
coast of Norway.

gale was blowing over the whole of the United Kingdom, and the area of high pressure had been displaced, and lay over the extreme south-west of France.

The next chart (fig. 52), for 6 P.M. on the 21st, shows us that the disturbance had made rapid progress east-

wards, and now lay over western Norway, while the winds in these islands had moderated in violence, and had veered towards North-west.

If we now turn back to fig. 17 (p. 83), we shall see the cause of the unnecessary warnings to which allusion has just been made.

At 8 A.M. on the 22nd, a brisk fall of the barometer took place in the west of Ireland, with a 'backing' wind, and warnings were at once issued, but, as will be seen by fig. 17, this was only a false alarm, for the fresh disturbance was only secondary to the more serious one which had preceded it, and its only effect was to equalise pressure in Ireland, by reducing the gradients and moderating the force of the wind.

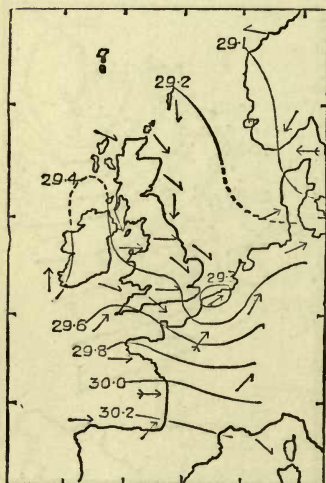


FIG. 53.—January 21, 1875; 8 A.M.
Small depression over Belgium.
New disturbance approaching
Ireland.

The storm which has been taken as a typical cyclone, that of November 29, 1874, whose course we have traced (figs. 19–22, pp. 90–92), is a good instance of a partial success and partial failure. On the 28th, warnings were issued to the west, north, and east of England, but not to the Channel coast or to the

French stations. It will be seen from fig. 21 (p. 91) that while the warning was quite successful on all the coasts to which it was issued, its omission was a signal failure at the southern stations.

It will be interesting to examine yet another case of failure of warnings, and one which has arisen from the unexpected direction of motion of the storm.

Fig. 53 (p. 158), for 8 A.M. January 21, 1875, shows us no less than three cyclonic disturbances over the area of our chart. One large one is disappearing over Norway. A very small secondary one is lying near Dover, while the third—the one we are about to trace—is just showing itself off the west coast of Ireland.

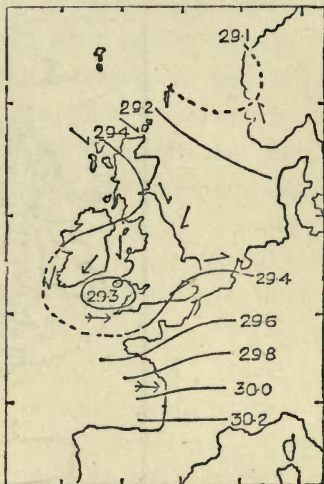


FIG. 54.—January 21, 1875; 2 P.M.
New disturbance near Pembroke.

Warnings were issued to all our own coasts excepting Scotland and the north-west of England, from Fleetwood northwards. Fig. 54, for 2 P.M. on the same day, shows us the disturbance with its centre near Lundy Island, while pressure over the south of France has barely changed since the morning.

At this time, however, the depression was becoming deeper, and was extending rapidly to the southward.

Fig. 55, for 6 P.M. on the same day, shows us the centre of the storm lying over Dover, and a very heavy gale from North-west is blowing all along the west coast of France, while our shores had nothing but moderate breezes.

These warnings, therefore, were quite unnecessary for

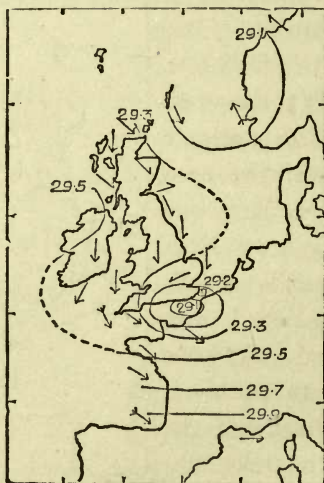


FIG. 55.—January 21, 1875; 6 P.M. New disturbance near Dover, in same position as that at 8 A.M.

several of the English stations to which they were issued, but they ought to have been transmitted to France, where they would have been of good service.

Lastly, a storm like that of April 20–24, 1872 (p. 103), which doubles back on its own course, naturally causes much difficulty in the issue of warnings.

The instances cited are sufficient to show that there is great uncertainty in the practice of storm warnings, owing to the deficiency of our information as regards quality and quantity, and that even with all the information we can procure we are often to a great extent in the dark as to the character and motion, in direction and rate, of the storms which approach our coasts, until they have wrought more or less damage.

With all these drawbacks, however, it has been shown at p. 153 that we are able to maintain a general success of about 80 per cent. for our warnings, a result on which we may fairly congratulate ourselves.

CHAPTER X.

FORECASTING.

THE recognised value of storm warnings to the seafaring community soon led to a general demand, on the part of the public, for predictions of the weather day by day. These were issued by Admiral FitzRoy almost at the first institution of storm warnings in 1861, but the forecast service was suspended at the end of 1866, and was not resumed for the space of more than ten years.

Meanwhile, the Meteorological System of the United States was organised, and it at once commenced the issue of its 'Probabilities.' This service speedily attained great popularity, owing to the very general correctness of the predictions. In our own country, however, forecasting was not taken up again until the re-organisation of the Office in 1877. The country was partitioned into eleven districts, the same division as has been adopted for the Weekly Weather Report, and which has reference to the predominant character of the agriculture in the different parts of the United Kingdom. The districts are shown in the accom-

panying map (fig. 56). The reason that Scotland North is called 0, is that when the division was first planned it was considered that the Highlands of Scotland were not strictly agricultural.

The principles of preparation of the forecasts are on the whole similar to those of the preparation of storm warnings, but the task is evidently much more difficult ; and besides the duty is constant, and not merely occa-

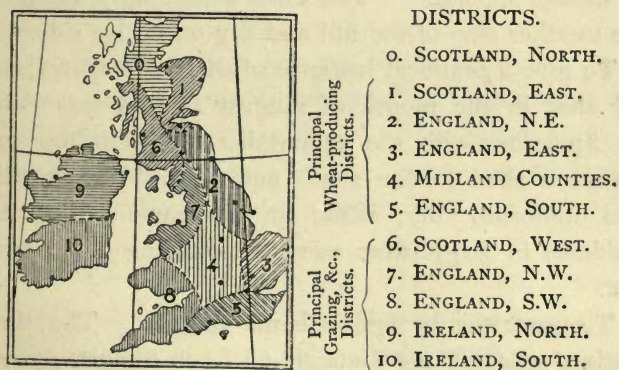


FIG. 56.—Chart showing Districts.

sional. The great difficulty consists in the fact that the weather is not, and cannot be, the same over the whole of each of the districts, for the variations in the contour of the country ; the hills and valleys ; the lie of the land, whether it faces north, south, east or west ; and its position with regard to the sea, all exert a great influence on its weather. More especially is this the case with regard to ranges of hills. Supposing such a

range to lie along a coast-line, the wind coming from the sea will be forced to rise over it. As it rises it is expanded by the reduction of pressure. In the process of expansion the air is chilled, and a proportion of the moisture in it is condensed and falls as rain. When the air reaches the ridge of the hills it begins to descend. It is compressed in the descent and warmed thereby, so that its tendency is not to produce rain but to absorb moisture. The air is accordingly damp on the weather side of the hill and dry on its lee side.

To give a practical instance of what is meant, I may say that in the month of August 1886 I was living on Speyside, with the mountains of Perthshire and Inverness-shire to the south and west. The weather was uniformly dry, while at the same period the residents in Argyllshire were complaining of constant wet.

To prove this by figures is not difficult. The three stations selected are Laudale on Loch Sunart, Argyllshire, among high hills, close to the coast; Glasgow Observatory, lying well to the south of the Grampians, but at some distance from hills; and Nairn, lying to the north-east of the hills of Inverness-shire. The following are the recorded rainfalls, in inches, in the months of August and September 1886:—

			August.		September.
Laudale	.	.	3.78	...	9.50
Glasgow	.	.	1.81	...	4.96
Nairn	.	.	1.19	...	2.47

It is not possible to frame forecasts which shall

exactly suit these different conditions existing in one district, but it is equally impossible for the forecaster in London to subdivide in his mind the districts with reference to all the local peculiarities of climate which exist in each, and to frame several hundred special forecasts.

Notwithstanding all these disadvantages, we are able to point to a very good proportion of success for our forecasts, as the figures shortly to be cited will show.

The forecasts are prepared three times a day, on the receipt of the several telegraphic reports, for 8 A.M., 2 P.M., and 6 P.M. respectively, as explained at p. 15. Each forecast is intended to cover the interval of twenty-four hours, and no more, from the time of its issue.

The 11 A.M. forecasts are intended for the early editions of the evening papers, for the clubs, and for public exhibition in various parts of London.

The 3.30 P.M. forecasts are not generally published, but in the summer-time they are issued to a limited number of gentlemen to aid them in the saving of the hay harvest. In this case the recipients engage to send in regularly to the Office reports as to the accuracy of the forecasts.

The 8.30 P.M. forecasts are supplied gratis to any newspaper which will send for them to the Office, as explained in the Annual Reports.

The forecasts are also issued to subscribers at a

small charge, and in addition the Office is always ready to answer, to the best of its ability, inquiries as to weather, for not more than twenty-four hours in advance, on terms which are published in the Postal Guide.

In order to check the accuracy of the forecasts, they are regularly compared with the weather reported in the various districts on the days to which they referred, and the results of this checking of the forecasts issued at 8.30 P.M. during the year 1885 is as follows :—

DISTRICTS.	PERCENTAGES.				Total Percentage of Success.
	Complete Success.	Partial* Success.	Partial* Failure.	Total Failure.	
Scotland, N. . .	55	31	9	5	86
Scotland, E. . .	50	35	10	5	85
England, N.E. . .	53	34	10	3	87
England, E. . .	53	31	11	5	84
Midland Counties . .	51	34	11	4	85
England, S. . .	57	31	9	3	88
Scotland, W. . .	48	30	12	10	78
England, N.W. . .	48	32	12	8	80
England, S.W. . .	50	32	12	6	82
Ireland, N. . .	46	35	11	8	81
Ireland, S. . .	46	33	12	9	79
Summary . . .	51	32	11	6	83

* Note, "partial" implies "more than half."

The forecasts have been issued and checked regularly since the beginning of the year 1879, and the following are the figures of the summary for the entire period of seven years, under the same headings as those just given :—

Years.	Complete Success.	Partial Success.	Partial Failure.	Total Failure.	Total Success.
1879	28	47	20	5	75
1880	35	40	16	9	75
1881	34	44	16	6	78
1882	44	35	13	8	79
1883	48	33	11	8	81
1884	51	31	11	7	82
1885	51	32	11	6	83

The Office, however, does not rest content with its own estimate of its own work, and accordingly the reports of the Hay Harvest Forecasts, which are furnished in the manner explained above, are tabulated and reduced to percentages. These figures therefore are quite independent of any possible colouring by the Office. The tables correspond exactly to those just given, except that they come down a year later, as the results for the season of 1886 have already appeared.

DISTRICTS.	NAMES OF STATIONS.	PERCENTAGES.				Total Percentage of Success.
		Complete Success.	Partial Success.	Partial Failure.	Total Failure.	
Scotland, N.	Golspie and Munlochy . .	62	24	11	3	86
Scotland, E.	Longniddry, Aberfeldy, Braco, Glamis . .	46	41	7	6	87
England, N.E.	Ulceby and Chatton, North-umberland . .	52	33	14	1	85
England, E.	Rothamsted and Thorpe . .	47	42	9	2	89
Midland Counties	Cirencester and East Retford . .	43	39	18	...	82
England, S.	Horsham, Maidstone, and Downton . .	49	38	12	1	87
Scotland, W.	Dumbarton, Stranraer, and Islay . .	66	20	13	1	86
England, N.W.	Leyburn, Knutsford, and Prescot . .	57	27	14	2	84
England, S.W.	Bridgend (Glamorgan), Clifton, Glastonbury, and Falfield . .	57	26	14	3	83
Ireland, N.	Hollymount and Moynalty . .	48	26	14	12	74
Ireland, S.	Moneygall and Kilkenny . .	54	31	13	2	85
Mean for all districts .		53	31	13	3	84

SUMMARY FOR THE LAST EIGHT YEARS.

Years.	Complete Success.	Partial Success.	Partial Failure.	Total Failure.	Total Percentage of Success.
1879	48	28	15	9	76
1880	38	38	20	4	76
1881	29	47	21	3	76
1882	50	37	11	2	87
1883	53	35	10	2	88
1884	43	42	12	3	85
1885	56	26	15	3	82
1886	53	31	13	3	84

At the risk of wearying the reader with a recapitulation of dry figures, this summary of results may be concluded with quotations of the figures obtained by independent private observers during the last year or two.

In the *Times* of February 7, 1887, a letter appeared from the Rev. G. T. Ryves, of near Stoke-on-Trent, giving his experience of the forecasts for the Midland Counties in 1886. The writer says:—

‘The forecasts were tested under six heads—viz., 1. Prevalence of rain, snow, or sleet. 2. State of the sky (whether clear, cloudy, overcast, or hazy). 3 and 4. Direction and force of wind. 5. Temperature (whether warmer or colder). 6. Electrical disturbances (lightning and hail). The success or failure of the forecast as to each head referred to in it was entered in its appropriate column, and the result was then entered in one of these columns (according as the actual weather agreed or disagreed with the forecast),

either as an absolute success, an absolute failure, or a partial or doubtful success.

'As no forecasts are issued on Sundays and Good Friday, and there were two days in December when it was impossible to issue any, owing to the breakdown of telegraphic communication, the number of forecasts sent out by the Office during the year was 310. Of these, 309 were tested in the manner above described, with the following result:—Absolute successes, 247; absolute failures, 26; partial or doubtful successes, 36. That is to say, we get, omitting small fractions, 80 per cent. of successes, $8\frac{1}{2}$ per cent. of failures, and $11\frac{1}{2}$ per cent. of doubtful cases.'

In the same connection it may not be without interest to give the following figures showing the results of the forecasts for England, SW., as tested at the Observatory Rousdon, Lyme Regis, by Mr. C. E. Peek, F.R.A.S., for the last three years. At this observatory the forecasts, arriving by post, are delivered about noon. The last entry of the weather for the period covered by the forecast is made at 9 A.M., and these facts are compared with the forecast on its arrival:—

Year.	Wind and Weather both reliable.	Wind only reliable.	Wind doubtful.	Wind unreliable.	Weather only reliable.	Weather doubtful.	Weather unreliable.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1884	59	69	20	11	73	17	10
1885	70	80	12	8	80	12	8
1886	73	80	11	9	85	8	7

The results of our work may be compared very fairly with those published by the other European Offices which issue forecasts. It is undeniable that occasion-

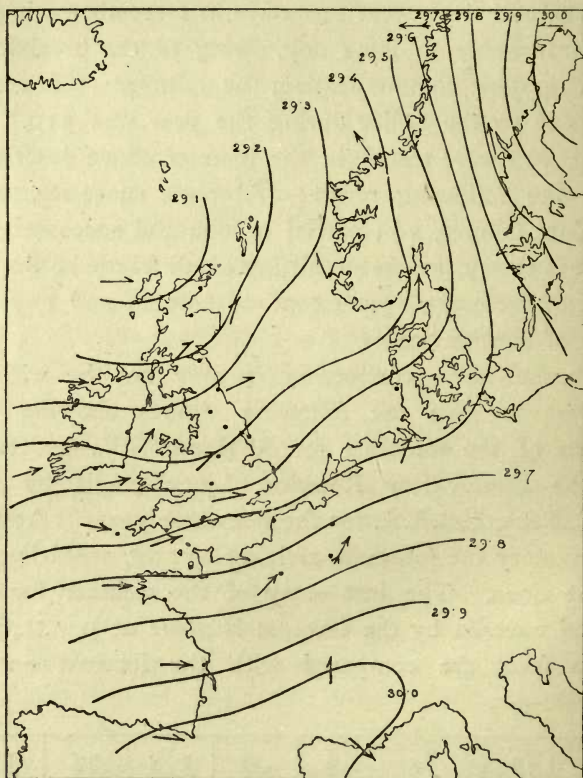


FIG. 57.

ally complete failures of the forecasts occur, and these are due very much to the same causes as the failures in storm warnings already described. A notable instance

of this may be cited, being that to which the Bishop of Carlisle drew notice in *Nature* for November 2, 1882.

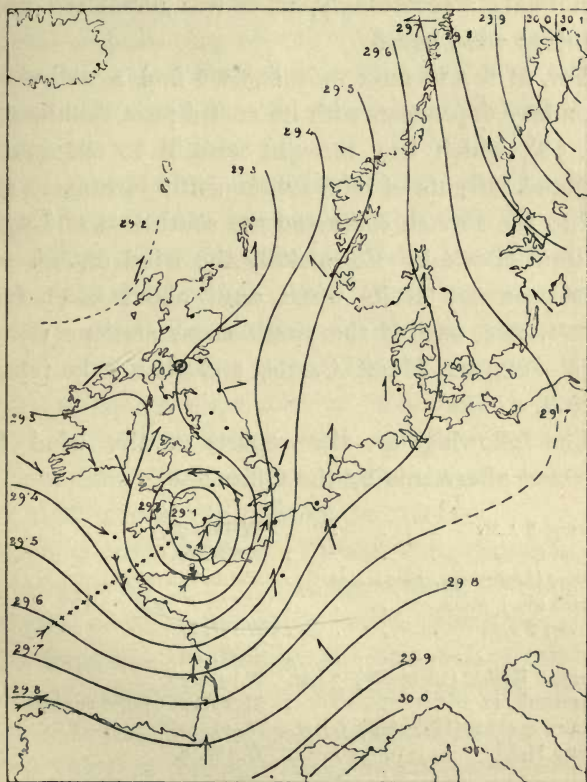


FIG. 58.

The date of the occurrence was October 24 in the same year.

The two charts (figs. 57 and 58) will show the completeness of the failure of the forecast. On the evening

of the 23rd (fig. 57), there was nothing in the reports from any of the stations to indicate the approach of any disturbance ; accordingly, none was forecasted and no warnings were issued.

Yet, at 8 A.M. next morning we find a well-marked secondary depression with its centre near Southampton (fig. 58), which has brought with it to the south of England torrents of rain, subsequently turning to snow, and to the French coast and the south-east of England a storm of wind. Fortunately the wind on our south coast was not at its worst until about noon, for at 8 A.M. not one of the south coast stations reported a gale except Hurst Castle, and that only reported force 8.

The following are the reports of the wind force collected afterwards by the Office :—

Jersey, 8 A.M.		WNW. 9*.
Hurst Castle		WSW. 10.
Owers (Lightship), 10-11 A.M.		SW.byW. 12*.
Varne (do.), noon		SW.byW. 10.
Dover, 2 P.M.		WSW. 8.
London		SSW. 10.
Kentish Knock (Lightship), 3 P.M.		W.byS. 10.
Yarmouth, 11 A.M.		SE.byE., 62 miles per hour.
Leman & Ower (Lightship), 6 P.M.		W. 10.
Spurn Head		WNW. 9.

Where no hour is stated none is given in the report. At the two stations marked, the force of 9 was reached before the warnings, which were issued at 9 A.M., could have reached the place, so that strictly speaking the warnings were issued before the gale had reached

a dangerous height, except in the Channel Islands and at the Owers Lightship, off Selsea Bill.

Now as to the possibility of foreseeing this gale, a careful examination of the photographic curves at the observatories shows that at Falmouth, the first to feel the influence of the disturbance, the barometer did not begin to fall till 10 P.M.

In a paper by Mr. H. Harries, 'On the Typhoon Origin of the Weather over the British Isles during the Second Half of October 1882,' which appeared in the *Quarterly Journal of the Royal Meteorological Society*, vol. xii. p. 10, this particular disturbance comes under notice, and the author says: 'I have examined the records of many ships over a large area west and south-west of the British Isles, but find nothing to justify our supposing that the storm had any existence at all until late on the night of the 23rd.'

After quoting facts to justify this assertion, Mr. Harries goes on to say: 'At the earliest, therefore, no prediction of an approaching storm could have been issued from the Meteorological Office before 3 A.M. of the 24th, and shortly after this hour the tempest was raging over the Channel and the French coast.'

This failure of forecasts attracted much attention, and various suggestions have been made to obviate the possibility of its recurrence. If we come to analyse these, we find they are two in number, and both of them have been more than once mentioned in these pages (pp. 15, 16). They are: I. More frequent

telegrams ; and II. More complete and accurate reports of the state of the sky.

More frequent telegrams demand a greater expenditure of money ; the telegraph offices close before nightfall, and to keep them open would cost a very large sum. In fact, it has well been said 'meteorology is money,' and at every turn we are met by the same difficulty of providing funds for any improvement. The second suggestion, that if a lunar halo, which was noticed in London at 10 P.M., had been reported two hours earlier, the Office might have had some intimation of impending change, is more practical ; but here, too, the fact is that the halo, if it existed at 6 P.M., was not reported from a single station, and the storm therefore took the Office at unawares.

It is needless to cite more instances of incorrectness of the forecasts ; they are all more or less similar in character to that which has just been quoted. Their correctness, on the contrary, is constantly being discussed in the newspapers, and in addition a large number of anonymous letters and postcards relating to the subject arrive at the Meteorological Office.

Many of these are very plain-spoken. One correspondent, whose handwriting is perfectly familiar to us, and who has been sending us postcards for years, says :

'Where is your violent cyclone to burst on British coasts between nights of 14 and 16? The deadest of calms, of course !' This individual holds the Office

responsible for the announcements of the *New York Herald*.

Another gentleman is straightforward enough to sign his name, and he says :

‘If you cannot give better information in your weather forecast you had better shut up your shop. You have been quite wrong every day this week. Go away, false prophet. I shall have a petition prepared to abolish your Office.’

Some of the letters are of a different tenor, and call for special forecasts. One arrived in June 1886, bearing no less than ten postmarks. It was addressed ‘Weather Office, Strand, London.’ Its contents were :

‘Three next days order to be fine.’

Another, of similar import, was addressed :

‘Clark of the Weather,
‘No. 1, Rainy Quarter.’

The Post Office added, ‘Try Meteorological Office.’ This letter was dated and reached us by first post.

Another was addressed :

‘Right Hon. Clerk of Weather,
‘9 Downing Street,
‘London, W.C.’

It ran as follows :

‘My Lord Clerk,
‘May it please your Lordship, you will greatly oblige your humble servant by writing or sending me

a telegraph whether it will be fine or not on the 5th of November 1867. I have the honour to remain,

‘Your Lordship’s most obedient servant,

‘JOSEPH WILLIAM ——.’

It need scarcely be said that this child received an answer, the letter being evidently in good faith.

The last to be mentioned is the prettiest of all. It reached me at Rome at the time of the meeting of the International Congress in 1879, and created great amusement among the *savants* assembled there. It was addressed :

‘On Her Majesty’s Service.

‘To the Clerk of the Weather,

‘Government Offices,

‘Whitehall, London.

‘To the Clerk of the Weather [*sic*].

‘Please Mr. Clerk of the Weather, tell the rain, snow, and hail to stop for the afternoon and rain in the night.

“Good bye, my dear old Clark [*sic*].

‘Go on next page.

‘My name is Blanche ——

‘Parsonage ——.’

Miss Blanche was duly informed that she was not the only person who cherished such wishes, but that her desires could not be fulfilled.

The number of weather prophets that write to us is very large indeed. Here is a verbatim copy of one letter :

‘April 28, 1879.

—— Colliery.

‘Notice Sir this to warn all shipowners and captans and all seefarenmen that there wil be sec storm, on the 16 or 18 of May from North East with rain lighting to get there ships trimed squalls of wind.’—This was duly signed.

The weather was perfectly calm between the 15th and 19th of May 1879.

One gentleman issued on postcards monthly forecasts for more than twelve months in 1882 and 1883. To each forecast was appended the following note :

‘These forecasts being founded on a universal law, allowance must be made for local differences and peculiarities. They are applicable to all places in the Northern Temperate Zone.’

The reader will have gathered from the foregoing pages that the weather is seldom quite the same on any one day all over the limited area of the British Isles. How then can we expect a forecast to be generally applicable when the North Temperate Zone embraces climates so different from ours as those of St. Petersburg and of Salt Lake City !

One thing is at all events admitted by all who have experience of forecasting, and that is that as yet no scientific principles have been established which enable us in Western Europe to forecast the weather for more than a few hours.

CHAPTER XI.

SUGGESTIONS FOR IMPROVEMENT.

IT will be seen, from what has been said in the foregoing pages, that there is room for improvement in the entire service, but improvement requires money, and money is limited. There is no lack of criticisms, friendly or the contrary, of our work, or of suggestions of new sources of information.

In some quarters the Meteorological Office is often expected to be far more venturesome in its announcements of weather than it is at all prepared to be. Once a gentleman called on us with the request that we would prepare for a newspaper, which he had recently started, a forecast of the probable weather for a week in advance. On our declining the task, he remarked that Admiral FitzRoy had issued forecasts for three days in advance, and that we ought to be able to do so for double that period. He quietly ignored the fact that Admiral FitzRoy's three-day forecasts were not successful enough for them to be continued, and that accordingly they had not been kept up.

Other men call on us to be as precise in our

announcements of 'probabilities' as the Chief Signal Office at Washington, in simple oblivion of the circumstance that while that Office has an immense continent to deal with, and is itself situated on the eastern side of its area of observation, so that the gradual march of weather changes over the western stations can be observed and reported long before they reach the more thickly populated portions of the States, we have to deal with an extended oceanic coast, and can by no possibility have a series of stations on our western side, so that, unless by the appearance of the clouds and sky, we have no chance of learning what is going on out of sight of land.

Our reporting system is shown on the frontispiece, and a glance at it will prove how badly we are off for stations on the west coast of Scotland. This is a most important district for gaining early intelligence of weather changes, but in the first instance telegraphic communication is only very scantily developed in such wild regions, and in the second place the habitable spots are almost all in sheltered bays, where the true force of the wind is hardly ever felt, owing to the fact that few ordinary houses could bear the brunt of a winter Atlantic gale, blowing, as it sometimes does, with a velocity of over 80 miles in a single hour, and reaching the speed of at least 100 or 120 in gusts. The observers therefore cannot possibly send up perfectly true reports of the direction and force of wind, as will be at once admitted when the position of the stations in

western Ireland and Scotland is considered. Valencia lies on the shore of a narrow sound, with high hills about it. Belmullet is at the head of Blacksod Bay, and is therefore quite sheltered from the sea, though its wind reports are good enough, as the land is low in the neighbourhood. Malin Head is well exposed. Ardrossan is a valuable station, but it is far up the Firth of Clyde, and at least fifty miles, as the crow flies, from the extreme western point of Islay. We have no other station till we reach Stornoway in the Island of Lewis.

The most obvious idea is to obtain information from the westward, either from moored signal ships, from islands such as the Azores, Faroes, Iceland, and Newfoundland, or lastly from the mainland of America.

Let us take these different suggestions in order.

The idea of the employment of ships moored at a distance from the coast, and connected by a telegraphic cable with the shore, has already been noticed in Chapter I. This plan has over and over again been suggested as a most valuable mode of obtaining information, not only of the position of vessels in distress or wind-bound, but of the meteorological conditions prevailing out at sea. Some scientific men, as the late Mr. Morse, have even gone so far as to propose that these signal ships need not even be manned, but might be simple buoys provided with electrically self-registering apparatus, which might record its indications automatically at the nearest station on land!

The plain state of the case about any such visionary projects is that, even if we were to overcome the difficulty of mooring a ship in 1000 fathom water, we should find it very difficult to maintain the telegraphic cable in working condition. Some years ago the Admiralty lent H.M.S. *Brisk* to be moored as a trial signal ship at the entrance of the Channel. The experiment was given up in six weeks, mainly on the ground of the difficulty of maintaining the telegraphic connection in a perfect state, and it was stated that the venture cost the promoters about as many thousand pounds as the *Brisk* was days at sea.

In the year 1886, however, the Telegraph Construction and Maintenance Co. succeeded in keeping up connection with the Sunk Lightship, off Harwich, for a year, so that the possibility of working such a scheme has been proved.

As regards reports from islands situated in mid-Atlantic, there is but little prospect of our ever making much progress in that direction. It has often been suggested that a cable should be laid from Portugal to the Azores, and that this country should bear a considerable share in the cost of daily telegrams from those islands, as it was assumed that, as the Azores are situated in the Atlantic, they must be, so to speak, pickets, to give us early news of danger approaching from that quarter.

All this is very plausible, but when we come to test the simultaneous reports taken daily in those islands

and at Valencia, as has been done at the Meteorological Office for two years and a half (*Quarterly Journal of the Meteorological Society*, vol. i. p. 183), we find that there is very little connection between the phenomena occurring at the two stations, so that we could get no *direct* warnings of approaching storms from the Azores, though of course a daily knowledge of the conditions of weather over the part of the Atlantic where those islands are situated could not fail to be of value to us, as is evident from what has been said in Chapter VI. In fact, the Azores lie to the southward of the usual track of Atlantic storms, and it would apparently be a far better investment of money for this country to spend it in obtaining reports from the Faroes, if ever a cable were laid to those islands, than in paying for telegrams from the Azores, as many of the most destructive storms on our north-east coast come down on us from the northern part of the Atlantic Ocean and pass over the Faroe Islands. The value of St. Kilda as an outpost could hardly be overrated, but there is no present hope of telegraphic connection with that island, and in all cases it must be remembered that unless a cable will pay commercially it is hopeless to look for the establishment of telegraphic communication for scientific purposes. The telegraphic connection of the Azores with Europe has been talked about for a quarter of a century, and repeatedly it has been announced that a concession for laying a cable has been granted, but up to the present date (April 1887) capitalists have not

been induced to put down the necessary sum. To give some idea of the expense which would have to be met if the cable were laid and maintained for scientific purposes alone, it is sufficient to say that such a scheme, for communication with the Faroes and Iceland, was proposed to the International Meteorological Committee at their meeting at Copenhagen in 1882, and that in that scheme the annual contribution of this country, ranged naturally in the first class for maritime importance, was £3285 for three daily reports, being more than we pay at present for all our home and European telegrams put together! The idea of maintaining cables for meteorological service alone may therefore be dismissed as visionary.

As regards reports from the other side of the Atlantic, in the year 1868 a direct service of reports from Heart's Content, Newfoundland, was organised. These messages were transmitted *gratis*, thanks to the great liberality of the Anglo-American Telegraph Co. It was found, however, that we could not turn them to practical account, mainly owing to the fact that the situation of the station of Heart's Content was in a sheltered nook, where no storm could hurt the shore end of the cable, and accordingly the wind reported by the observers bore little relation to that blowing at sea outside. The service was therefore discontinued in the year 1871.

Speaking in general terms, we may say, as regards storm warnings from America, that though storms do

sometimes cross the Atlantic from shore to shore, they change their character *en route*, some increasing and others dying out, so that we cannot predict which storm, out of several starting from the States, will reach us. Professor Loomis, a very high authority on American weather, very strongly supports the view just stated in the following words, taken from the *American Journal of Science and Art* for January 1876:

‘When storms from the American continent enter upon the Atlantic Ocean they generally undergo important changes in a few days, and are frequently merged in other storms which appear to originate over the ocean, so that we can seldom identify a storm in its course entirely across the Atlantic.’

To give an instance of a storm failing to advance over any great distance, I shall take one which is very striking. On November 30, 1874, the steamer *La Plata*, with a telegraph cable on board, foundered in a heavy gale near the Channel Islands. This storm entirely died out and disappeared before it crossed the North Sea.

These statements show how rash is the opinion which is held by Professor Daniel Draper, of New York, and announced in the Reports of the Central Park Observatory for 1872 and 1873, to the effect that out of eighty-six storms which he had investigated, as having started from New York, only three had failed to show themselves either at Valencia or Falmouth.

We now come to the practical results of Atlantic Telegraphy, as it has been conducted of late years. In February 1877, owing to the great public spirit of Mr. J. G. Bennett, the Weather Bureau of the *New York Herald*, under the late Mr. J. J. Collins, commenced the transmission by telegraph of Weather Warnings to Europe. These messages have been continued ever since; they appear in the public press, and so have attained an extensive circulation.

When these warnings were first issued, their general purport was to the effect that a disturbance was on its way across the Atlantic, and might be expected to cause gales on the western coasts of Europe at a given date. The following is a specimen of these messages—it arrived July 4, 1877:

‘Storm centre will arrive British, French coasts, probably 5th or 6th; NE. to SW. gales, rains and lightning. Warn outward-bound ships.’

The practical utility of these warnings has been carefully tested in our own Meteorological Office, for the first year of their continuance, and of late by Professor Cleveland Abbe, of the Chief Signal Office, Washington: the results in both cases are much the same. About one-quarter of the warnings are followed by gales of any consequence on the British coasts.

The actual percentages which my discussion, published in the *Nautical Magazine* for March 1878, yielded, were as follows:

Absolute success	.	.	17.5
Partial „	.	.	25.0
Very slight „	.	.	15.0
Absolute failure	.	.	42.5
			100.0

The paper goes on to say :—‘These figures show that not 45 per cent. of the warnings (in 1877) can be considered to be really successful. What is meant by “really successful” is that the information conveyed by them was of real value to seamen in British ports.’

Professor Cleveland Abbe, of the Chief Signal Office, Washington, states in a letter addressed to myself :

‘A full report on the verifications of the *New York Herald* predictions was submitted by me to the late General Myer, in January 1878 : this covered all cases of published predictions up to November 29, 1877, and in it I allowed the *Herald* 42 per cent. in all—*i.e.*, about 25 per cent. for well-verified predictions and 17 per cent. for partial successes, and for the remaining 50 per cent. [*sic*] of failures. This was for Great Britain, but for France and Spain the percentages were decidedly less. These were of course *apparent* verifications, and took no account of the fact that sometimes storms arrived in Great Britain and served to verify a prediction, whereas they really were different and distinct from the storms to which the predictions referred.’

It will be seen that Professor Abbe’s investigation refers to a portion of the same period to which my inquiry referred. It is very satisfactory to see that the two discussions, totally independent of each other, confirm each other so completely.

Of late years the *Herald* warnings have been generally couched somewhat in the following words:—
‘A disturbance is central near Newfoundland, and may be expected to disturb the weather of the British Isles, &c., at such and such a date.’

These telegrams have been much more successful than the positive predictions of gales, as the phrase ‘disturbance of weather’ allows considerable latitude, and it is a fact that if a storm even approaches our coasts, it cannot fail to disturb our weather to a certain extent, at least in Ireland or Scotland.

To give an idea of the extent to which storms striking our coasts could really be predicted by means of reports from America, the late Captain Hoffmeyer, the head of the Danish Meteorological Service, who himself had drawn and published daily weather maps of the Atlantic for the space of three and a quarter years, investigated the course of Atlantic storms in a pamphlet which he published in 1880. He discussed 285 depressions in all, covering an interval of twenty-one months, and found the following percentage proportions of the storms prevailing over the ocean source of depression:—

Source of Depression.	Existing in Long. 40° W.
Arctic Regions	8
North America	44
Probably Tropical	9
Secondary, arising at sea	37
Untraceable	2
	100

It will be seen from this that not one-half of the

storms which existed in 40° W. came from the United States. Now of the 285 storms only 145, or, in round numbers, one-half, passed the meridian of 10° W., and these were thus divided in percentages:—

Source of Depression.	Passing Long. 10° W.
Arctic Regions	12
North America	47
Probably Tropical	5
Secondary, formed at sea	33
Untraceable	3
	100

We see therefore that of the storms which reach us, not quite one-half could possibly have been predicted by telegrams from America. The figures given above show that the actual successes attained by prediction were much less than this.

For the last few years the Meteorological Office, in conjunction with the Bureau Central Météorologique in Paris, has been in regular receipt of telegrams forwarded by the Chief Signal Office, Washington, and conveying intelligence of storms met with by steamers arriving at American ports. It was considered that if a steamer encountered a storm to the westward of the meridian of 45° W., she could reach an American port before the storm could reach Europe. Accordingly, timely intelligence from her log might be transmitted by telegraph to Europe. It has not, however, been found practicable as yet to issue warnings based solely on these telegrams, but their receipt puts us on our guard.

We learn therefore from all this, that we in the United Kingdom have to rely on our resources and our own stations, for gaining information for storm-warning purposes, and so we must only do our best to improve our own arrangements.

It is evident that, if we had an extensive continent like North America to deal with, we too, in the Meteorological Office, could probably make good our claim to a proportion of successes for our warnings, rivalling that with which the Chief Signal Office is justly credited. That this is not an idle boast is shown by the following figures taken from the Report of the Meteorological Office (the Norddeutsche Seewarte) at Hamburg for 1874. A system of warning for Hamburg from our Office had then been in operation since 1867, and the general results were, that 301 warning messages were issued from London in the course of the seven years. 72 per cent. of these warnings were followed by gales, while *in only three cases* did the storm outrun the message. Naturally in these figures no account is taken of the gales missed owing to the Sunday interruption of our service which prevailed up to 1877.

The reason of this success in issuing to Hamburg timely warning of all storms, a success which is far more brilliant than we can ever show for our own coasts, is that our network of stations, as will be seen from the frontispiece, entirely surrounds the North Sea, and that no storm can reach Hamburg without passing over our outposts, unless it comes from the Continental

side, a very unusual direction for its advance. As a proof of this statement I may say that in the year 1869 twenty-three storms were felt in Hamburg, and twenty-two of these had previously passed over some part of the United Kingdom.

Finally, we come to the subject of high-level stations, such as that on Ben Nevis. A considerable number of such stations has been organised. Among these we may mention, in the United States, Pike's Peak and Mount Washington; in Portugal, Sierra da Estrella; in France, the Pic du Midi, Puy de Dôme, and Mont Ventoux; in Switzerland, the Säntis; in Italy, Mont Cimone and others; in Austria, the Sonnblick and Hoch Obir; in Germany, the Brocken and Schneekoppe; and there are several others.

The discussion of the results they yield has led to most interesting conclusions in relation to the diurnal march of temperature, barometrical pressure, and the force of wind at different levels, and more especially as to the changes in the dampness and the temperature of the air produced by its passage over mountain chains.

The popular idea of the value of these stations is, however, that they are mainly of importance as weather-reporting points. On this head I recently inquired in Europe and the United States, of the chiefs of the meteorological services which possess such stations, as to what practical benefit their forecasting service derived from these reports.

The outcome is very scanty and quite incommen-

surate with the cost and labour of maintaining the stations, *supposing these to be kept up solely for forecasting purposes.*

The late General Hazen replied that no telegraphic reports were received from Pike's Peak, but that the information from Mount Washington was of considerable value in weather prediction for the adjacent New England States.

From Europe the replies were less decided. Professor Mascart said that the reports from the Pic du Midi were often of value in giving early warning of floods in the low country, owing to the melting of snow. He also stated that the reports from that station and from the Puy de Dôme indicated shifts of wind before any signs of their approach were noticeable at the lower level.

The other directors gave no positive reply. On one point all authorities are in accord, that the barometrical readings cannot well be used in forecasting. This arises mainly from difficulties connected with the reduction of the readings to sea-level. It is very interesting to learn that the barometrical oscillations at the summit of Ben Nevis are particularly sudden and extensive, but no indication has yet been given of the mode of using such information in forecasting.

It must always be remembered that the preparation of forecasts and storm warnings is necessarily a rapid proceeding, and it must be carried out with intelligence, often defective, especially in stormy weather, when completeness of information is most desirable. The

calculations therewith connected must above all be of a simple nature, and such as can be carried out by assistants of ordinary education.

In conclusion, I can only say that the foregoing pages contain what is, necessarily, a very condensed and brief abstract of the present state of our knowledge of weather, in so far as this knowledge depends on the system of Weather Telegraphy, a branch of investigation which is confessedly of great intricacy.

To do the subject justice, double the space, and at least treble the number of charts and illustrations, would have been required. If, however, the contents of these pages shall have awakened in any of my readers a real conception of what the weather work of the Meteorological Office is, and an interest in the careful study of weather, one of the most enticing of all inquiries—not to mention its practical importance to every one—the trouble of putting together these notes will have been far more than repaid.

CHAPTER XII.

THE WEEKLY WEATHER REPORT.

IN addition to the Daily Weather Reports, which have been the theme of the preceding pages, the Office has for the last nine years issued weekly returns containing information intended to be used in agricultural and sanitary investigations. The subjects on which data are given in this publication are—Temperature, Rainfall, and the Duration of Sunshine.

In the year 1884 the character of this Report was much improved, and its size was considerably enlarged, and a specimen of the summary of results which now appears weekly will be found on pp. 194, 195.

This table appears in a somewhat abridged form in the London newspapers on Thursday mornings, and in several agricultural papers at the end of the week.

The nature of the information as to Rainfall and Sunshine is easily intelligible: it consists of statements of the amount of each recorded for the week, and of the quantity which has accumulated since the beginning of the year. In each case the difference from the average is given.

Figures for week ending April 25 - 1887.

TEMPERATURE OF THE AIR.																			
DISTRICTS.	OBSERVED DURING THE WEEK.				Above or below the Mean for the Week.	ACCUMULATED.													
	Highest.	Lowest.	Averages of			For the Week.			From January 4, 1887.										
			Daily Maxima.	Daily Minima.		Daily Mean.	Above 42°.	Difference from Mean.	Below 42°.	Difference from Mean.	Above 42°.	Difference from Mean.	Below 42°.	Difference from Mean.					
0. SCOTLAND, NORTH	60	30	48.5	37.3	43.0	0	Day-deg. 27	13	Day-deg. 493	Day-deg. 196	282	56	7	71	642	162	155	152	
1. SCOTLAND, EAST	58	30	51.6	37.2	44.1	1 below	35	13	528	56	17	73	73	73	73	73	73	73	73
2. ENGLAND, N.E.	64	32	54.3	40.0	46.8	0 (average)	42	6	530	7	530	236	7	530	236	7	530	236	7
3. ENGLAND, EAST	67	33	57.8	39.9	48.4	1 below	54	6	642	234	234	234	71	642	234	71	642	234	71
4. MIDLAND COUNTIES	67	31	56.3	38.8	47.1	2 below	49	9	628	279	279	279	53	628	279	53	628	279	53
5. ENGLAND, SOUTH	70	32	56.3	40.2	47.8	2 below	48	5	510	284	284	284	73	510	284	73	510	284	73
6. SCOTLAND, WEST	58	33	50.6	40.8	45.5	1 below	30	3	408	249	249	249	11	408	249	11	408	249	11
7. ENGLAND, N.W.	57	32	51.0	41.0	45.8	3 below	31	3	480	209	209	209	56	480	209	56	480	209	56
8. ENGLAND, S.W.	65	28	53.4	39.5	46.1	4 below	39	7	388	315	315	315	76	388	315	76	388	315	76
9. IRELAND, NORTH	64	28	51.9	40.7	46.0	2 below	33	4	349	333	333	333	11	349	333	11	349	333	11
10. IRELAND, SOUTH	64	28	53.1	40.4	46.5	3 below	38	4	312	406	406	406	24	312	406	24	312	406	24
— CHANNEL ISLANDS	59	38	52.7	43.7	48.0	2 below	42	0	170	312	312	312	134	170	312	134	170	312	134

DISTRICTS		RAINFALL.						BRIGHT SUNSHINE.			
		FOR THE WEEK.			FROM JANUARY 4, 1887.			FOR THE WEEK.		FROM JANUARY 4, 1887.	
		Number of Rainy Days.	Total Fall.	More or Less than the Mean for the Week.	Number of Rainy Days.	Difference from Mean.	Total Fall.	Difference from Mean.	Hours Recorded.	Percentage of Possible Duration.	Difference from Mean.
Principal Wheat-producing Districts.			roths of In.								
0. SCOTLAND, NORTH.	..	6	15	10 more	69	- 4	Ins. 13.9	Ins. +2.8	12	12	- 3
1. SCOTLAND, EAST.	..	6	9	4 more	51	- 5	6.4	-2.7	22	21	+ 2
2. ENGLAND, N.E.	..	5	4	1 less	48	- 7	4.4	-2.9	30	30	+10
3. ENGLAND, EAST.	..	5	5	1 more	41	-16	4.3	-2.4	42	42	+ 6
4. MIDLAND COUNTIES.	..	4	3	1 less	40	-14	4.5	-3.4	37	37	+ 4
5. ENGLAND, SOUTH.	..	5	5	1 more	41	-12	4.9	-3.3	48	49	+ 5
Principal Grazing, &c. Districts.											
6. SCOTLAND, WEST.	..	7	20	10 more	56	- 9	11.8	?	27	27	+ 5
7. ENGLAND, N.W.	..	5	7	2 more	44	-14	6.7	-3.0	29	29	+ 7
8. ENGLAND, S.W.	..	5	7	1 more	44	-17	6.2	-7.0	44	44	+10
9. IRELAND, NORTH.	..	6	13	8 more	54	-16	8.6	-1.8	26	26	+ 3
10. IRELAND, SOUTH.	..	6	11	5 more	47	-19	8.9	-3.9	38	38	+ 9
— CHANNEL ISLANDS.		5	9	4 more	49	-19	5.6	-4.9	54	55	+10

The statistics as to Accumulated Temperature, however, are not so easily intelligible, as at the head of the column we find the entry 'day-degrees,' which calls for some explanation.

At one of the Conferences in connection with the Health Exhibition in 1884, I read a paper on Cumulative Temperature, which is here reproduced, as giving an explanation which it is hoped will be sufficient for the reader.

'As to the growth of crops, Sir J. B. Lawes, Bart., F.R.S., and Dr. Gilbert, F.R.S., have for many years conducted with scrupulous accuracy extensive investigations into this subject at the famous experimental farm of Rothamsted. Let us therefore hear what they have to say :—

"On this point we may remark that we have found the really most luxuriant and heavy crops, both of hay and of wheat, to have been very materially influenced by the characters of the winter and early spring periods—*quantity* in both cases depending very greatly on the early development of the plant. With favourable conditions in this respect some of our very heaviest crops, both of hay and wheat, have been obtained under by no means specially favourable meteorological conditions during the period of most active above-ground growth. On the other hand, high proportion of corn to straw, which sometimes gives really high yield per acre, depends more upon the conditions of the periods of active above-ground growth and maturation.

In the same way, great weight of hay sometimes depends upon the conditions of maturation rather than of luxuriance.

“It is obvious, therefore, that in discussing the relations of meteorological condition and agricultural production, it is essential to be able to arrange the records for any selected periods of the year.”

‘And again :—

“It is obvious that different seasons will differ almost infinitely at each succeeding period of their advance, and that, with each variation, the character of development of the plant will also vary, tending to luxuriance, or to maturation, that is, to quantity, or to quality, as the case may be. Hence, only a very detailed consideration of climatic statistics taken together with careful periodic observations in the field, can afford a really clear perception of the connection between the ever-fluctuating characters of season and the equally fluctuating characters of growth and produce. It is, in fact, the distribution of the various elements making up the season, their mutual adaptations, and their adaptation to the stage of growth of the plant, which throughout influence the tendency to produce quantity or quality. It not unfrequently happens, too, that some passing conditions, not indicated by a summary of the meteorological register, may affect the crop very strikingly, and thus the cause will be overlooked, unless careful observations be also made and the stage of progress, and tendencies of growth, of

the crop itself at the time, be likewise taken into account."

' Again :—

' "Those characters of season which are very unfavourable for land in poor condition, may be favourable to land in high condition, and *vice versâ*."

' As regards the three elements represented on the diagrams,¹ it is evident that the curves for rainfall and sunshine require but little explanation, as the successive steps of the curves show the successive weekly totals of rain or sunshine.

' The case as regards temperature is, however, different, and those who examine the diagrams will see that there are two curves, one ascending, the other descending. A certain arbitrary base line is assumed, and the values are measured above or below that line.

' It is proved, almost beyond a doubt, that each plant, say each individual cereal, requires a definite amount of heat to bring it to maturity. Thus, maize requires more than wheat, and wheat again more than barley or oats.

' We all know that maize is not an English crop at all, and that wheat is not grown to much profit in Ireland or the west of Scotland, being replaced by oats or barley. The ordinary reason assigned for these differences as to crops is that in each case the temperature is not high enough for the particular crop

¹ Diagrams were exhibited in the Meteorological Annexe. These are not reproduced here.

which has failed. If the inquirer pursues the subject further he generally finds out that his informant has no very precise idea as to how the temperature acts.

‘Now various investigators, and notably Boussingault and Professor Alphonse de Candolle, of Geneva, have devoted much attention to this subject, and the latter writer, in his “Géographie Botanique,” has come to the conclusion that a certain total amount of temperature above a definite base line is necessary for plant growth, and that this amount, or, as he calls it, this “sum of temperature,” varies for each crop.

‘He finds that plants, as a rule, do not begin to give indications of active vegetation until the temperature rose above 6° Cent. This temperature, 6° Cent., or in round numbers, 42° Fahr., that is ten degrees above the freezing-point, is taken as the base for all the diagrams.

‘Although Professor de Candolle propounded his views some years ago, yet as recently as the year 1874, at the Agricultural Conference at Vienna, meteorologists were quite at sea as to how these sums of temperature were to be calculated.

‘The credit of solving this problem belongs to Lieut.-General Richard Strachey, the Chairman of the Meteorological Council. He proposes to adopt a certain unit of temperature to supply a standard for calculation, the unit being one degree continued for the unit of time, either one hour or one day, as the case may be. Such a unit may be conveniently called

an hour-degree, or a day-degree. The unit of time adopted for the calculations to which I am about to refer is a day, and the unit of what may be termed the effective temperature is therefore *a day-degree*. A day-degree therefore signifies one degree Fahr. of excess or defect of temperature above or below 42° Fahr., continued for twenty-four hours, or any other number of degrees for an inversely proportional number of hours.

‘Now, the first idea I want you to take in about these day-degrees is that, when we speak generally of the mean or average temperature for a day, or month, or year, we imply that the resulting temperature is the same as would be observed if the thermometer indicated this mean temperature throughout the entire period for which the mean is taken. Thus, if we were dealing with daily means, an average daily temperature of 62° Fahr., which is an ordinary temperature for a warm summer’s day, would indicate twenty day-degrees of temperature for that day, starting from the assumed base line of 42° Fahr., which has already been mentioned.

‘The first step therefore towards determining this effective temperature in day-degrees resolves itself into determining as speedily and simply as possible the average temperature for the period under consideration.

‘We have, fortunately, to our hands, a very simple mode of arriving at the mean temperature with accuracy sufficient for our purposes. Almost all observers record the maximum and minimum temperatures once in the

twenty-four hours. It is found that the half sum of these readings, the mean between them, is nearly, but not exactly, the average for the day. It must, of course, be understood that the instruments must be read regularly and at the same hour every day.

‘The next points which require attention are: whether the maximum and minimum are both above 42° , which occurs in summer, or both below that point, which occurs in winter; or, finally, whether one is above, and the other below.

‘In the first case all the accumulated temperature is to the good; it is all on the positive side. In the second case it is all on the negative side. The third case is the only one which presents difficulty, for when the extreme temperatures are on either side of the line of 42° , one portion of the effective temperature for the day is positive and the other negative.

‘Now, General Strachey carried out a long series of calculations, based on the observed hourly temperatures at Kew Observatory, and at other stations in the United Kingdom, in order to ascertain the magnitude of the co-efficient by which the difference between either of these extreme temperatures and the base temperature (42° Fahr.) should be multiplied in order to obtain the values of the temperatures in excess or defect of 42° Fahr. expressed in day-degrees, and he found that this, *for a weekly period*, was $0^{\circ}.4$.

‘Accordingly we get the following rules:—

‘If the mean of the day is above 42° Fahr., we

multiply the difference between the minimum and 42° by 0.4 (four-tenths), and call this *the negative effective temperature*.

‘To find *the positive effective temperature* we subtract from the difference between the mean for the day and 42° , the negative effective temperature just determined.

‘If the mean of the day is below 42° Fahr. the proceeding is similar ; but we first ascertain the positive effective temperature, and subtract that from the difference between 42° Fahr. and the mean, thus obtaining the negative effective temperature.

‘The method of determining the effective temperature, which may briefly be called the accumulated temperature, is fully explained in a paper by General Strachey, which was published in the volume of the Quarterly Weather Report for 1878.

‘The practical application of the data thus obtained as standards of comparison for the growth and ripening of various agricultural products must, of course, be left to the agriculturists, and it will be interesting to learn how far a correspondence between the character of the several crops and the accumulated temperature of the year can be established.

‘The measure of temperature afforded by this system of computation appears to be as well suited to supply a standard of comparison of climates for hygienic purposes as for agriculture, and the diagrams indicate in a forcible manner the characteristic differences of

climate, in respect of temperature, of the portions of our islands to which they refer.'

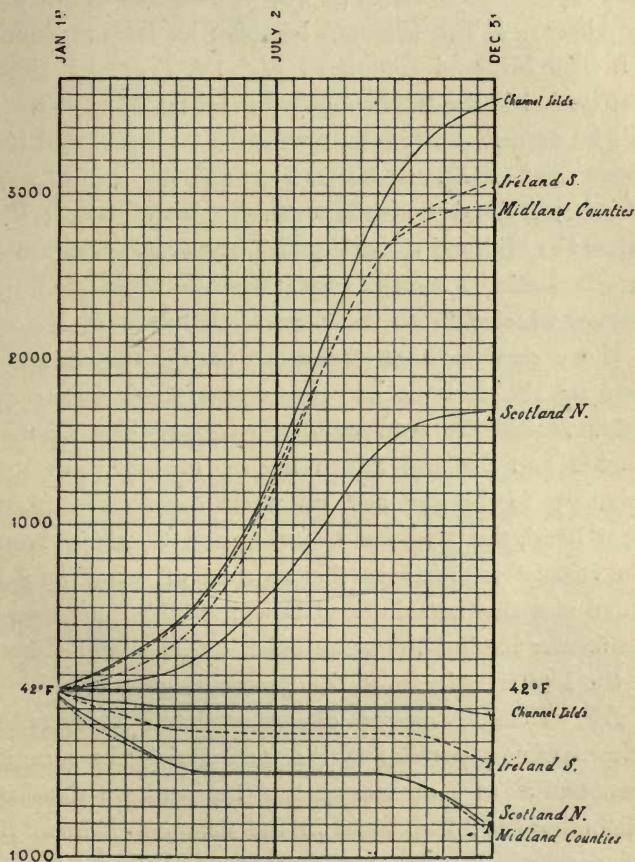


FIG. 59.

Diagram showing the curves of Accumulated Temperature, above and below 42°, for the period 1878-1885, in various districts.

By way of illustration of the foregoing, the curves of accumulated temperature for four of the districts have been reproduced in fig. 59 (p. 203). The districts selected have been—I. The Channel Islands; II. Ireland South; III. The Midland Counties; and IV. Scotland North. The period is the interval of eight years, 1878–85. It will be seen that the total amount of accumulated heat above 42° Fahr. is highest, 3547° , in the Channel Islands; Ireland South comes next, with 3064° ; then follow the Midland Counties, with 2931° ; and last of all comes Scotland North, with 1890° , only one-half the amount which falls to the share of the Channel Islands.

If we now look at the lower part of the diagram, showing the amount of accumulated heat below 42° Fahr., it will be seen what advantages the Channel Islands and Ireland South derive, mainly from their exposure to the sea and its warm currents. On the other hand, the Midland Counties and Scotland North run closely together in the amount of what may be called negative accumulated heat, the inland position of the former having the same effect on its winter climate as the higher latitude of the Scotch Highlands.

All of these curves of accumulated temperature below 42° run parallel to the base during the summer, inasmuch as at that season the temperature does not fall below 42° ; but while in the Channel Islands the point at which this condition is reached is 93° , it is 239° in Ireland South, 504° in the Midland Counties, and 510° in Scotland North.

It will also be noticed how very closely the curve for Ireland South follows that for the Channel Islands at the beginning of the year, while during the autumn it practically coincides with that for the Midland Counties.

As regards the use which may be made of these data, a paper on the Connection between the Accumulated Temperature and Agricultural Production was read by Professor J. H. Gilbert, F.R.S., before the Société Helvétique des Sciences Naturelles, and published in the 'Bibliothèque Universelle,' vol. xvi. (3rd Period), and of this some extracts may be interesting.

Dr. Gilbert gives the following table :—

AGGREGATE EXCESS OF DAILY MEAN TEMPERATURE above 42° F. from Fixed Dates, or from Commencement of Active Above-ground Growth, to Date of Harvest at Rothamsted.

Years.	From Jan. 1.	From Feb. 1.	From March 1.	From April 1.	From date of Excess nearly Every Week.	From Date of Weekly Excess after a Break.
	°	°	°	°	°	°
1878	1999	1950	1864	1768	1999	1950
1879	1990	1990	1962	1881	1990	1961
1880	1995	1976	1899	1744	1976	1976
1881	1816	1814	1804	1699	1814	1804
1882	2018	1968	1891	1703	2026	1966
1883	1790	1743	1665	1628	1772	1645
1884	1847	1757	1687	1561	1847	1686
1885	1774	1752	1674	1601	1774	1696
Mean	1904	1869	1806	1698	1900	1836

Dr. Gilbert says : 'The results show that for wheat, from the Meteorological Office figures, the total number of aggregate degrees of heat is, for the last two columns, 1900° and 1836° respectively.

‘Hervé Mangon’s results, for north-west France, give 1854° , which is not far from the Rothamsted figure.

‘Risler’s figures, for Nyon in Switzerland, correspond to 2192° .

‘Boussingault and Hervé Mangon have both investigated the question for barley, and their results give respectively, for spring-sown barley 2005° and 1989° , nearly approaching the Rothamsted values for wheat.

‘Boussingault’s results for maize correspond to 3515° .’

The foregoing extract is sufficient to show one direction in which the figures representing accumulated temperature may be turned to account, but the number of years for which this information is available is as yet too small to allow of many important deductions being drawn from them.

CHAPTER XIII.

ON CIRRUS CLOUD OBSERVATIONS.

THE following Instructions, devised by the Rev. W. Clement Ley, were adopted by the Meteorological Council in 1885, and have been issued to such of the observers connected with the Office as are willing to undertake the reporting of cirrus movements :—

The attention of the observer is especially directed to clouds of the ‘cirrus’ type, including what are here defined as *true cirrus*, *sheet-cirrus*, *high cirro-cumulus*, and *cirrus-haze*. They are the highest kinds of cloud, and it is to these types only that the following Instructions refer.

True Cirrus.—When in moderate quantities it is commonly white, though when seen through haze it is usually somewhat cream-coloured, and when the sun’s rays have reached it through a long stratum of hazy atmosphere, is often of either an orange or rosy tint. In all cases it has a very delicate appearance. It is sometimes arranged like bunches of fine hair ; and such tufts of cirrus are often called ‘mare’s tails.’ At other times it resembles small curled feathers. Quite as

commonly, however, it lies in thin light strands, like pale gossamer threads.

Sheet-Cirrus.—When cirrus overspreads as a continuous sheet a large portion of the sky it becomes what is here termed '*sheet-cirrus*.' In this state, when not too thick, it produces 'halos' or large rings round the sun and moon. The sheet-cirrus sometimes appears fibrous, sometimes reticulated. When the veil of this cloud becomes thick it assumes some neutral or muddy tint, except in those cases when it is so disposed that the rays of the rising or setting sun are reflected to us from its under surface, which then appears of either an orange or rosy colour.

'*High cirro-cumulus*' differs from simple cirrus in consisting of small detached masses somewhat rounded in form, a great flotilla of which is often seen in the sky, especially in fine summer weather. Clouds at lower levels are frequently disposed in the same manner, but the observer must be very careful to distinguish between these and the high cirro-cumulus, which latter is either white, or changes its colour under the same circumstances as true cirrus, *no part of any of the cloudlets ever seeming to be decidedly thrown into shadow* by another part. The *high cirro-cumulus* also possesses the same faintness and delicacy of outline which we observe in cirrus.

Cirrus-Haze.—Sometimes cirrus is only visible as either a milky or an oily-looking haze, which is here termed '*cirrus-haze*.'

I.

Amount.—Whenever on looking round the sky the observer notices clouds of the kinds above described, he should in the first place endeavour to ascertain their *amount*. In doing this he should observe whether they cover, (1) only a trifling portion ; (2) about a quarter ; (3) about a half ; (4) about three-quarters ; or finally, the whole of the sky. The *extent*, not the *density*, of the cloud is here referred to. If there be any considerable quantity of lower cloud in the sky, so that the amount of upper cloud cannot be accurately ascertained, it should be invariably entered as doubtful, by a ‘?’

II.

Direction of Movement.—The next thing to be attended to is the direction from which the upper clouds move. Considerable difficulty will here be encountered. If some of the clouds happen to be nearly overhead, attention should at first be confined to such ; and if possible the observer should so place himself as to have the projecting corner of a roof or chimney, the summit of a steeple, flagstaff, or other stationary object, very close to the line between his eye and the portion of cloud which he is about to watch.

A convenient plan is to set up a pole reaching 5 feet $7\frac{1}{2}$ inches above the level of the observer's eye ; a mark or ring should be placed round the pole at the

latter level. The summit of the pole must carry two thin rods, fixed crosswise, and set truly to the four cardinal points. Through or near the extremities of these rods should pass a thin circular iron ring of 3 feet diameter, the use of which will be mentioned presently. The observer should, when opportunity offers, so station himself that some recognisable part of a cloud appears to move vertically either upwards from the top of the pole, or vertically downwards towards it. The direction of the pole from the observer's position, which may be judged of by the cross rods, is then, in the first case, the direction of the upper current; in the second, its opposite. In watching the movements of the clouds, the observer may conveniently use a staff, one end of which is sharpened so as to stick in the ground, while the other is fitted with a crescent-shaped top in which to rest the arm, in order to support and steady the head. If the clouds be observed from a window it is some assistance to have a few wires—some horizontal, others vertical—fastened across the window to the wall on the outside.

When, however, no part of the cloud is moving directly either towards or away from the observer, the effects of the perspective render it difficult to estimate the direction of movement exactly. To perfect oneself in the art, it is advisable as often as possible to endeavour to estimate the direction of movement of some portion of the cloud which is inconveniently placed, and then to find the actual direction of

movement of another portion of the same cloud, or same sort of cloud, which happens at the time to be conveniently placed. By patiently practising the eye in this process the observer eventually learns to make, automatically, tolerably exact allowance for the errors arising from perspective. In no case (should he have the least doubt as to the direction of movement) must any conjecture be telegraphed, but the figure for 'motion doubtful' should be inserted in the telegram.

It is always well, when observing the movements of the upper clouds, either to rest the head against a wall or tree, or to support it on a staff, or by some other means, so as to be quite motionless while taking an observation.

III.

Apparent Velocity.—The next particular to be attended to is the *apparent velocity of motion* in the clouds—*i.e.*, the force of the current which carries them. The observer is requested to notice whether the cloud be actually motionless, or whether its motion is *very slight*, *moderate*, *rapid*, or *very rapid*. Clouds of the cirrus type are seldom really motionless, but owing to their great distance they commonly, though not always, appear to move more slowly than the lower clouds. To estimate, even according to the very rough scale proposed, the apparent velocity of movements, we have to encounter precisely the same difficulties which have presented themselves in finding the direction, and the

training of the eye requisite for deciding this is identical. A cloud which is near the horizon of course presents much less movement to the eye than one which is near the zenith, because it is at a much greater distance; and further, the *apparent* movement of clouds which are travelling either across, or more or less obliquely to, the line of sight, is different from that of clouds which are travelling directly to or from the zenith. To test the accuracy of his estimate of the apparent velocity of clouds moving crossways and obliquely, the observer should, when occasion offers, compare it with his estimation of the apparent velocity of clouds in the same stratum passing overhead at the time. To test the accuracy of his latter estimation he will do well occasionally to notice how many seconds of time a recognisable portion of upper cloud takes in travelling 15° on the sky, to or from the zenith. The pole arrangement already described can be employed for this purpose. In the last case a recognisable portion of cloud must be first caught in the zenith, the observer looking up the pole, applying his eye as closely as he can to the ring or mark above mentioned. He should then note the time, and again at the moment when the selected portion of cloud, as viewed from this spot, reaches the circular wire. The time taken by the cloud in passing over this distance from the zenith, which is (approximately) 15° , should be then noted. When clouds of the cirrus type take a longer time than 600 seconds (or ten minutes) in traversing 15° to

or from the zenith, their motion should be regarded as 'very slight.' When a less time than this, but a longer time than 300 seconds, or five minutes, as 'moderate ;' when less than 300 seconds but more than 60, as 'rapid ;' and lastly, whenever they take a less time than 60 seconds, as 'very rapid.'

It may be mentioned that in simply looking at the sky without the aid of any appliance, inexperienced observers commonly estimate the position of the zenith wrongly because they do not throw the head far enough back.

IV.

'*R.-point.*'—Clouds of the cirrus kind very commonly lie in streaks, lines, or bands. Attention must next be given to the direction of these lines—*i.e.*, their *position* with respect to the points of the compass *altogether irrespective of the motion of the clouds.* When one of these bands happens to pass through the zenith, the point at which it reaches, or, if continued, would reach, the horizon, is to be noted. This point is called, for convenience' sake, the *R.-point*, or 'point of radiation,' because the cirrus bands, while really parallel, appear in perspective to radiate from this point, or rather from one beyond it, and beneath the horizon. It is, however, comparatively seldom that a cirrus band happens to lie immediately over the observer's head: the bands usually appearing in perspective as arches, or portions of arches, lying in any

part of the sky, and variously inclined to the horizon, according to their distance from the observer. It is easy in these cases to find the R.-point, if we imagine ourselves able to travel over the earth's surface so as to get immediately under one of these bands. The best plan, however, is to note, first, the point on the horizon which lies beneath the summit of any visible complete arch of cirrus. If there be no complete arch, but only a short thread visible, the observer should extend his arm so as to point with the forefinger towards this thread, and then pass the arm briskly two or three times backwards and forwards from one part of the horizon to another, continuing as closely as he can the curve of the cirrus thread. The point on the horizon which is immediately beneath the highest part of the curve so formed should then be noted, and in every case the R.-point will be a point at right angles to this point on the horizon.

It is obvious that there must always be two R.-points opposite to each other. Although it is in itself immaterial upon which of these the observer fixes, he is requested as a matter of convenience, when he has already found a point *from which the upper clouds move*, to report the R.-point which is nearest to that direction, if one of the two be nearer than the other. For example, if cirrus travels from WNW. and lies in strands which are disposed lengthwise NW. and SE., the R.-point NW. should be reported in preference to the R.-point SE.

The 'selvedge' or margin of a sheet of cirrus usually gives the R.-point in the same way as a streak of detached cirrus. And when sheet-cirrus or cirrus-haze completely covers the sky, a warp may frequently be seen in it which supplies the same datum.

Cross rays or tangled threads may very often be noticed, frequently transverse or nearly so to the cirrus bands. These are especially discernible in some varieties of sheet-cirrus, when they form what we may call the 'woof' of the cloud sheet, and give to the latter the reticulated appearance already mentioned. No notice of these threads is required in the telegrams. In rather common cases, however, the cross threads are so marked that it is impossible to decide whether a particular point of the compass, or one at about right angles to it, is rightly to be regarded as the R.-point.

V.

Lastly, whenever a bank of cloud of this type appears on any horizon, or whenever being overhead, or nearly so, such a bank appears thicker in one part of the sky than in the other parts, the observer is to report the position of bank (*i.e.*, the direction in which the bank lies or in which it is thickest) and its density. The direction will not *necessarily* be at right angles to the R.-point, though it most commonly is so.

As to results from these observations, our experience of them is too short to enable us to say much, but the

following is a brief summary of the most obvious applications of cirrus observations in weather prediction :—

During bright weather and Westerly (NW. to SW.) airs or light winds, the appearance of very high clouds of the mare's-tail type, moving from the North-westward, is usually an indication of a backing of the wind to the Southward, and its increase in force, probably to a fresh or strong gale. This movement of the very high clouds under such conditions is especially dangerous, if at the same time a batch of such clouds be rising in the west, and the barometer, after rising, is inclined to fall again.

Again, when the wind is Westerly or North-westerly of moderate strength, if high hair-like or thready clouds appear moving from N. or NNE., they very commonly portend a great increase of wind from the North-westward, with snow, sleet, or soft hail in winter.

Again, if the wind be Easterly, and high clouds appear, similar to those just mentioned, but moving steadily from SSW., they point to an increase in the force of the Easterly wind ; and during sultry summer weather, to the early approach of thunderstorms, followed probably by a shift of wind to the South-westward.

In all these cases, however, the direction of the wind at the surface must be carefully noted ; and it may be added that the value of the sign is increased when it occurs after a spell of exceptional bright weather and a sudden rise of the barometer.

APPENDICES.

APPENDIX A. p. 62.
SUNDAY, 8 A.M. WEATHER REPORT. NOVEMBER 29, 1874.

STATIONS.	BAROMETER.		THERMOMETERS (in shade).					WIND.			Amount of Cloud, 0 to 10.	Weather, by Beaufort Scale.	Rainfall in Past 24 Hours.	Sea Disturbance, 0 to 9.				
	At 8 A.M. Reduced to 32° F. at the Mean Sea-level.	Change since Yesterday.	At 8 A.M.	Change in the Dry Bulb since Yesterday.	In Past 24 Hours.		At 8 A.M.	Extreme.	Direc.	Force (0 to 12).					Direc.	Force (0 to 12).		
					Dry Bulb.	Wet Bulb.											Max.	Min.
Haparanda	29.82	-.36	11	11	*	*	-2		N.	2	2	N.	2	2	0			
Hernösand	29.83	-.34	9	5	*	*	-12		Z.	0	2	N.	2	2	0			
Stockholm	29.82	-.28	30	30	*	*	-2		E.NE.	2	2	E.	2	2	0			
Wisby	29.86	-.23	31	31	*	*	-2		SE.	4	2	E.	4	2	0			
Christiansund	29.71	-.31	27	25	*	*	-1		ESE.	2	0	Z.	2	0	6			
Skudenes	29.55	-.42	37	32	*	*	+1		E.	8	6	E.	6	6	6			
Oxö (Christiansund)	29.60	-.42	37	34	*	*	+6		E.	6	6	NE.	6	6	6			
Skagen (the Scaw)	29.69	-.34	35	33	*	*	+1		ESE.	4	4	ESE.	4	4	4			
Fanö	29.48	-.42	32	32	*	*	0		SE.	4	4	S.	4	4	4			
Cuxhaven	29.43 f	-.44	32	31	?	30	-2		SE.	5	5	SE.	5	5	5			
Sumburgh Head	29.32 f	-.27	41	41	43	38	-1		SE.	7	6	SE.	7	6	6			
Stormoway (Hebrides)	29.03 f	-.37	42	39	45	39	-2		E.	6	6	SSE.	6	6	6			
Thurso	29.17 f	-.37	40	39	43	38	+1		ESE.	5	5	SSE.	5	5	5			
Wick	29.12 f	-.40	40	39	44	38	-1		SE.	7	7	S.	7	7	7			
Nairn	29.07 f	-.44	37	36	47	36	0		SE.	2	5	SE.	2	5	5			
Aberdeen (9 A.M.)	29.02 f	-.56	41	39	43	38	+3		E.	7	8	SE.	7	8	8			
Leith (9 A.M.)	28.87 f	-.69	40	40	42	32	+7		SE.	10	3	S.	10	3	3			
Shields	28.81 f	-.82	41	41	43	32	+8		SE.	10	10	SE.	10	10	10			
York	?	?	42	42	43	34	+10		E.	3	3	E.	3	3	3			

For explanation of the columns see p. 220.

Scarborough (10.30 A.M.)	28.59 f	-1.05	44	44	+10	44	34	SE.	10	9	SE.	10	or	0.85	7 *
Nottingham	28.61 f	-1.03	45	45	+14	45	30	SSE.	2	7	ENE.	10	r	0.82	8
Ardrossan	28.78 f	-.73	40	38	+5	40	35	E.	6	6	E.	9	h	0.04	3 *
Greencastle (9 A.M.)	28.79 f	-.62	749	749	+6 ?	44	39	ESE.	2	7	E.	10	gd	0.20	5 *
Donaghadee	28.75 f	-.77	41	40	-2	43	41	NE.	6	7	ESE.	10	rd	1.12	4
Kingstown	28.67 f	-.78	43	42	-3	51	43	WNW.	6	6	SSE.	10	r	1.66	5
Holyhead	28.55 f	-.91	44	44	+3	46	40	ENE.	2	5	E.	10	r	0.87	3
Liverpool (Bidston Obs.)	28.57 f	-.97	41	40	+9	41	32	E.	3	8	E.	10	mf	0.74	...
Valencia	29.04 r	-.25	43	42	-5	50	42	N.	6	8	N.	7	pq	0.32	7
Roche's Point	28.92 f	-.41	45	43	-2	51	42	NW.	10	10	NW.	7	rc	0.45	5
Pembroke	28.68 f	-.75	46	45	+2	52	42	WNW.	10	10	WNW.	10	rq	1.19	7
Portishead	28.60 f	-.94	45	45	+9	45	34	S.	4	7	S.	7	qu	0.76	3
Scilly	29.01 f	-.42	51	48	+1	54	44	WNW.	10	11	NW.	6	ohq	0.45	7
Plymouth	28.81 f	-.65	48	47	+1	55	45	WNW.	6	8	WSW.	10	gq	0.81	4
Hurst Cast'e	28.65 f	-.90	49	49	+5	62	45	WNW.	7	7	WNW.	5	rq	1.17	6
Dover	28.80 f	-.77	50	48	+14	51	34	SSW.	6	5	S.	8	cu	0.07	5 *
London	28.63 f	-.99	49	47	+14	55	35	S.	2	5	SSE.	7	gq ^o	0.71	*
Oxford	28.65 f	-.95	47	46	+12	51	35	SSW.	1	3	SE.	10	r	0.93	*
Cambridge	28.67 f	-.96	47	47	+17	47	30	SSW.	2	3	SSW.	10	gs ^o	0.67	*
Yarmouth	28.74 f	-.92	37	29	0	48	35	S.	5	5	SE.	10	gr	0.72	5
Helder	not received on Sundays	...	*	*	...	*	*	...	...	...	*	*	*	*	...
Cape Gris Nez	28.86 f	-.75	50	48	+23	?	?	S.	7	3	SE.	7	or	0.36	5
Brest	?	...	52	50	...	56	47	W.	9	11	SW.	10	rf	0.47	8
Lorient	29.15 f	-.34	51	47	+5	58	41	WNW.	9	9	WNW.	7	r	0.20	8
Rochefort	29.48 f	-.11	55	50	+10	?	43	WNW.	12	4	SE.	10	m	0.43	7
Biarritz	29.75 r	+ .13	56	54	+4	56	53	W.	7	5	W.	10	ro	0.16	5
Corunna	30.00	...	55	*	...	*	*	SW.	6	*	*	*	po	*	7 *
Brussels	29.01	-.67	46	*	+12	*	*	SSE.	4	*	*	*	rc	*	*
Charleville	29.25	-.54	43	*	+11	*	*	S.	3	*	*	*	o	*	*
Paris	29.15 f	-.49	49	*	+17	40	38	SSW.	7	3	SE.	10	o	0.20	*
Lyons	?	?	51	*	+10	*	*	S.	6	*	*	*	c	*	*
Toulon	29.79 f	+ .01	48	46	+8	48	42	E.	1	5	E.	10	ro	...	2

NOVEMBER 28, 2 P.M., REPORTS AND REMARKS.

STATIONS.	Bar.	Dry.	Wet.	Wind.		C.	Wea.	Sea.
Skudesnaes .	29.87	37	33	?	6	*	o	4
Thurso .	29.48	41	39	SSE.	5	8	o	3
Scarborough .	29.55	37	35	SSW.	2	10	o	3
Greencastle .	29.30	43	42	ESE.	5	10	g	*
Holyhead .	29.34	44	43	SSE.	2	10	d	1
Valencia .	29.12	48	48	E.	2	8	r	5
Scilly .	29.26	51	51	S.	6	10	d	6
London .	29.53	39	38	SE.	2	10	omg	*
Rochefort .	29.60	50	48	SE.	4	10	m	3

The barometer continues to fall, excepting at Rochefort, most on our SW. coasts, and the wind at Valencia has backed to E. The sea is increasing at the mouth of the Channel, and rain falls along our western coasts. Warnings issued to our W. and N. coasts.

EXPLANATION OF COLUMNS.

BAROMETER.—The letters r (rising), f (falling), and s (steady), indicate the motion of the mercury in last 14 hours. EXTREME WIND is the strongest wind experienced in past 24 hours. WEATHER: see p. 10.

* *An Asterisk* is inserted in all places for which information is not usually received. The 'extreme' wind for the Swedish, Norwegian, and Danish stations is an observation taken at 8 P.M.

REMARKS.

For Sunday, November 29, 1874, at 8 a.m.

During the past twenty-four hours a serious fall of the barometer has taken place over the United Kingdom, amounting to more than an inch at Nottingham; and the centre of a very deep and well-defined depression has advanced to Wales and the western central parts of England. From Corunna to Pembroke there is a gradient of 0.13 inch per 50 miles for W. winds; while from Skudesnaes to Holyhead there is one of 0.10 inch for SE. winds.

Temperature has risen very considerably at all but the most western stations. Over central England the change amounts to 14° in the twenty-four hours.

Strong SE. gales have set in on our NE. coast, while very strong W. to NW. gales are felt in the SW. and Bay of Biscay, and S. winds in the SE. of England. The sea runs very high, especially in the N. and NE.

Very heavy rain has fallen over the whole of the United Kingdom, accompanied by hail and snow in some places; the fall continues at most stations. The weather is extremely unsettled.

NOTE.—The chart which faces this page is reduced from the Daily Weather Chart, but is printed in the form in use in 1887, not in that which actually appeared in 1874.

BAROMETER, WIND & SEA.

(Explanation of Map)

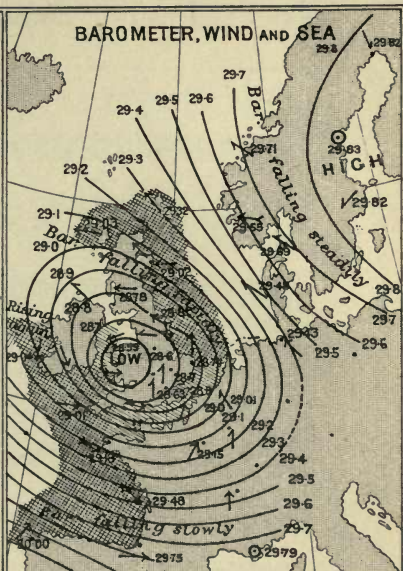
Barometer — Isobars are drawn for each tenth of an inch. Changes since previous morning are stated in words.**Wind** — Arrows show the prevalent winds. They fly with the wind and their barbs and feathers refer to force, thus —

→ forces above 10; → forces 8 to 10;
 → forces 5 to 7; → forces 1 to 4;

○ — dead calm.

Sea Disturbance — where considerable is shown thus
 — Rough. — High.**MEAN HEIGHT of the BAROMETER**at 8 a.m. for the month of July.
During the 10 Years 1871—1880.

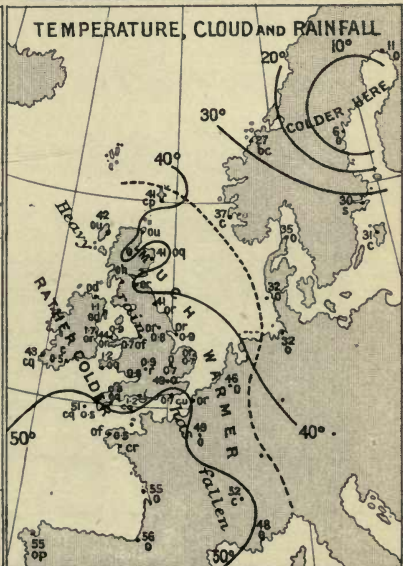
STATIONS.	MEAN READINGS.
Bumbargh Head	29.827
Stornoway	29.790
Wick	29.818
Nairn	29.824
Aberdeen	29.829
Leith	29.945
Glasgow	29.873
York	29.902
Ardrossan	29.864
Donaghadee	29.875
Holyhead	29.914
Liverpool	29.910
Valencia	29.944
Boche's Point	29.940
Pembroke	29.945
Selly	29.905
Hurst Castle	29.961
Dover	29.969
LONDON	29.965
Oxford	29.941
Cambridge	29.987
Yarmouth	29.984

**TEMPERATURE, & WEATHER at 8 A.M.,**
with RAINFALL in PAST 24 HOURS.**Temperature** — Isotherms are drawn for each 10° changes since previous morning are stated in words.**Weather** — is shown by Letters of the Beaufort Scale.**Rainfall** — A dotted line separates the districts in which rain has fallen from those where there has been none. Falls of 0.5 in. or more, are quoted in figures.**MEANS OF TEMPERATURE IN SHADE.**
AND RAINFALL.

for the month of July.

STATIONS	TEMPERATURE				RAINFALL (Inches)
	Daily Max.	Daily Min.	At 8 a.m.		
			Dry.	Wet.	
Bumbargh Head	57.9	48.5	53.7	33.2	3.00
Stornoway	60.2	40.7	50.4	34.2	3.08
Wick	53.4	40.4	46.2	33.9	2.25
Nairn	66.0	51.6	57.4	33.7	3.57
Aberdeen	64.4	51.7	57.9	34.4	3.74
Leith	66.0	53.0	59.1	35.9	3.64
Glasgow	64.0	53.6	58.5	35.5	3.68
York	68.1	53.3	59.7	36.5	3.97
Ardrossan	64.0	53.5	57.5	34.9	3.91
Donaghadee	63.9	53.0	57.7	35.9	3.67
Holyhead	64.5	55.0	58.3	36.1	3.33
Liverpool	66.4	54.6	59.6	36.1	3.90
Valencia	64.5	53.9	59.0	36.3	3.91
Boche's Point	66.3	53.9	59.7	36.0	3.16
Pembroke	64.0	54.4	58.5	35.2	3.31
Selly	65.0	56.9	60.3	35.3	3.29
Hurst Castle	67.9	56.4	61.7	35.3	3.15
Dover	67.4	57.5	63.0	35.3	3.82
LONDON	73.3	54.3	63.5	35.6	3.17
Oxford	69.9	53.7	60.4	37.1	3.51
Cambridge	72.5	52.6	61.3	35.0	3.30
Yarmouth	66.7	55.5	61.4	36.4	3.68

Notes — The Temperature means are for the 10 years 1871—80, the Rainfall means are mainly those for the 20 years 1868—85



APPENDIX B.

Hourly Readings of the self-recording instruments at Valencia Observatory, March 26, 27, 1874, p. 67.

Appendices.

221

MARCH 26.										MARCH 27.									
Hour.	Bar.	Temp.		Tension of Vapour.	Wind.		Rain.	Hour.	Bar.	Temp.		Tension of Vapour.	Wind.		Rain.				
		Dry.	Wet.		Direction.	Velocity.				Dry.	Wet.		Direction.	Velocity.					
1	...	...	...	...	...	...	...	1	29.726	51.8	51.2	.369	S. by E.	46	...				
2	...	...	...	...	...	...	...	2	29.714	52.0	51.3	.369	S. by E.	46	...				
3	...	...	...	...	...	...	...	3	29.698	52.1	51.7	.379	S.	45	...				
4	...	...	...	...	...	...	...	4	29.672	52.3	51.8	.379	S. by E.	41	0.030				
5	...	...	...	...	...	...	...	5	29.650	52.2	51.8	.380	SSE.	39	0.020				
6	...	...	...	...	...	...	...	6	29.634	52.0	51.6	.377	S. by E.	40	0.030				
7	...	...	...	...	...	...	...	7	29.598	52.4	51.8	.377	S. by E.	44	0.115				
8	...	...	...	...	...	...	...	8	29.564	52.7	51.9	.375	S.	48	0.065				
9	...	...	...	...	...	...	...	9	29.546	52.7	50.7	.344	S. by W.	54	...				
10	...	...	...	...	...	...	...	10	29.546	52.6	50.2	.332	SSW.	58	...				
11	30.004	50.9	49.2	.329	SSE.	39	...	11	29.556	51.0	48.0	.299	SSW.	58	...				
Noon	29.990	50.8	49.4	.335	SSE.	37	...	Noon	29.554	51.8	47.8	.285	SW. by S.	63	...				
1	29.978	51.0	50.0	.348	SSE.	42	...	1	29.594	50.0	46.7	.280	WSW.	58	...				
2	29.924	50.8	50.0	.351	SSE.	40	0.005	2	29.678	49.2	45.7	.268	W. by S.	44	0.010				
3	29.874	50.7	50.0	.352	SSE.	46	0.005	3	29.724	49.7	46.5	.279	W.	34	...				
4	29.874	50.6	49.7	.346	SSE.	44	...	4	29.768	51.0	46.2	.259	W.	33	...				
5	29.850	50.7	49.8	.347	S. by E.	46	...	5	29.816	49.0	45.9	.274	W. by N.	27	...				
6	29.814	50.7	49.8	.347	SSE.	51	...	6	29.874	48.9	44.0	.236	WNW.	22	...				
7	29.806	50.6	49.9	.351	S. by E.	46	0.050	7	29.916	48.3	44.8	.257	WNW.	19	...				
8	29.794	50.9	50.0	.349	S. by E.	45	0.010	8	29.956	47.6	42.3	.215	WNW.	17	...				
9	29.778	51.4	50.7	.361	S.	50	...	9	29.984	47.0	42.3	.220	WNW.	15	...				
10	29.772	51.6	50.9	.363	S. by E.	48	...	10	...	...	...	...	...	...	...				
11	29.766	52.0	51.2	.366	S.	50	...	11	...	...	...	...	...	...	...				
Midnight	29.742	51.9	51.2	.367	S.	48	...	Midnight	...	...	...	...	...	...	...				

APPENDIX C.

Hourly Readings of the self-recording instruments at Aberdeen Observatory, October 20, 21, 1874, p. 71.

OCTOBER 20.										OCTOBER 21.									
Hour.	Bar.	Temp.		Tension of Vapour.	Wind.		Rain.	Hour.	Bar.	Temp.		Tension of Vapour.	Wind.		Rain.				
		Dry.	Wet.		Direction.	Velocity.				Dry.	Wet.		Direction.	Velocity.					
1	...	...	...	...	...	...	...	1	29.079	50.7	46.6	.271	SSW.	30	...				
2	...	...	...	...	...	...	...	2	28.962	49.4	47.4	.303	S. by W.	28	...				
3	...	...	...	...	...	...	...	3	28.827	50.1	48.0	.308	S.	28	...				
4	...	...	...	...	...	...	...	4	28.657	50.1	48.2	.313	S. by W.	29	...				
5	...	...	...	...	...	...	...	5	28.529	51.9	49.5	.324	SSW.	30	...				
6	...	...	...	...	...	...	...	6	28.407	52.0	50.0	.335	SSW.	23	0.010				
7	...	...	...	...	...	...	...	7	28.326	51.0	48.3	.306	SW. by S.	24	...				
8	...	...	...	...	...	...	...	8	28.314	51.0	47.9	.297	SW. by W.	35	0.030				
9	...	...	...	...	...	...	...	9	28.344	45.4	42.6	.241	W. by S.	46	0.020				
10	...	...	...	...	...	...	...	10	28.419	42.5	41.4	.248	W.	55	0.010				
11	...	...	...	...	...	...	...	11	28.644	40.8	40.8	.255	NW. by W.	57	0.180				
Noon	...	29.597	48.8	45.4	SW. by S.	24	...	Noon	28.777	40.5	40.0	.241	WNW.	57	0.080				
1	29.566	49.2	46.0	.274	SSW.	23	...	1	28.876	41.7	38.7	.204	WNW.	50	0.005				
2	29.551	50.1	46.5	.275	SW.	22	...	2	28.988	41.0	38.0	.197	WNW.	41	0.005				
3	29.546	50.5	46.9	.279	SW. by S.	14	...	3	28.995	40.8	37.4	.189	WNW.	42	0.005				
4	29.536	49.0	46.4	.285	SSW.	14	...	4	29.061	41.0	37.6	.190	W.	32	...				
5	29.529	48.6	46.1	.282	SSW.	11	...	5	29.095	39.3	36.1	.180	W. by N.	36	...				
6	29.522	47.4	46.0	.293	SW. by S.	9	0.010	6	29.109	40.0	36.0	.172	W.	34	...				
7	29.499	47.0	45.4	.284	SW. by S.	9	...	7	29.109	40.2	36.5	.179	W.	32	...				
8	29.454	47.5	46.0	.292	SSW.	11	...	8	29.114	40.5	37.0	.185	W.	32	...				
9	29.408	48.0	46.5	.297	S. by W.	12	...	9	29.111	40.2	38.2	.209	W. by S.	30	0.015				
10	29.341	48.9	47.3	.306	S.	14	...	10	29.124	40.0	38.0	.207	W. by S.	27	...				
11	29.254	50.5	48.5	.317	SSW.	24	...	11	29.128	42.1	39.3	.211	W. by N.	40	0.015				
Midnight	29.172	51.3	48.1	.297	SSW.	35	...	Midnight	29.136	42.5	39.0	.202	W.	41	0.005				

APPENDIX D.

Hourly Readings of the self-recording instruments at Falmouth Observatory, Feb. 1, 2, 1873, p. 75.

Appendices.

223

FEBRUARY 1.										FEBRUARY 2.									
Hour.	Bar.	Temp.		Tension of Vapour.	Wind.		Rain.	Hour.	Bar.	Temp.		Tension of Vapour.	Wind.		Rain.				
		Dry.	Wet.		Direction.	Velocity.				Dry.	Wet.		Direction.	Velocity.					
1	...	...	...	...	...	...	...	1	28.948	42.2	41.2	.247	ESE.	51	0.070				
2	...	...	...	...	...	...	...	2	28.923	45.2	44.3	.280	SE.	29	0.040				
3	...	...	...	...	...	...	...	3	28.896	45.7	44.3	.275	SSE.	23	0.030				
4	...	...	...	...	...	...	...	4	28.863	46.2	44.5	.274	S. by E.	26	0.010				
5	...	...	...	...	...	...	...	5	28.833	46.0	43.8	.261	S. by E.	22	0.010				
6	...	...	...	...	...	...	...	6	28.803	44.7	43.0	.257	SSE.	28	0.020				
7	...	...	...	...	...	...	...	7	28.773	44.7	42.5	.247	SSE.	29	...				
8	...	...	...	...	...	...	...	8	28.720	44.7	42.3	.242	SE.	35	0.035				
9	...	...	...	...	...	...	...	9	28.708	44.9	42.4	.242	SE. by E.	37	...				
10	...	...	...	...	...	...	...	10	28.667	44.5	42.3	.245	E. by S.	37	0.035				
11	...	...	...	...	...	...	...	11	28.637	43.9	42.0	.245	E. by N.	46	0.010				
Noon	...	...	...	...	...	...	...	Noon	28.631	43.8	42.4	.254	NE.	46	0.010				
1	29.610	40.6	38.6	.212	ESE.	42	0.010	1	28.661	44.2	42.8	.259	NE. by N.	46	0.020				
2	29.563	40.0	38.4	.215	ESE.	44	0.010	2	28.719	38.5	37.6	.215	N. by E.	40	0.030				
3	29.520	39.6	38.4	.219	ESE.	46	0.055	3	28.787	38.3	36.6	.198	N. by E.	36	0.005				
4	29.475	39.7	37.8	.206	SE. by E.	44	0.085	4	28.873	36.3	34.7	.185	N. by E.	35	0.005				
5	29.430	39.0	37.2	.203	ESE.	53	0.060	5	28.953	35.0	33.3	.170	N. by W.	36	0.005				
6	29.379	39.0	37.4	.207	ESE.	55	0.075	6	29.039	34.9	32.7	.160	NNW.	35	...				
7	29.331	39.0	37.4	.207	ESE.	59	0.070	7	29.108	34.7	32.4	.157	NNW.	35	...				
8	29.223	38.0	37.0	.208	ESE.	63	0.090	8	29.161	34.6	32.3	.157	N. by W.	33	...				
9	29.168	36.8	36.0	.202	ESE.	59	0.140	9	29.203	35.3	33.0	.162	N. by W.	33	...				
10	29.129	37.0	36.0	.200	ESE.	64	0.150	10	29.262	35.8	33.9	.175	NNW.	29	...				
11	29.048	37.4	36.4	.204	E. by S.	62	0.130	11	29.303	36.0	33.7	.170	NNW.	27	...				
Midnight	29.013	39.4	38.3	.220	ESE.	65	0.060	Midnight	29.345	35.6	33.0	.160	NW. by N.	30	...				

INDEX.

ABB

ABBE, Cleveland, on results of *New York Herald* warnings, 186.

Aberdeen Observatory, curves for October 21, 1874, 73; readings for same period, 222.

Accumulated temperature, calculation of, 196; curves of, for United Kingdom, 203.

America, value of telegraphic reports from, 184; present service of telegrams from, 188.

Anticyclones defined, 36, 40; illustration of, 40; characteristics of, 57; typical, 59; motion of, 93.

Ascending motion, effect of, on air, 57, 164.

Atlantic Ocean, advance of storms over, 15, 117, 183; cost of telegraphy across the, 183.

Atlantic weather, Hoffmeyer on, 187.

Aurora as sign of storm, 117.

Azores, possible value of telegraphic reports from, 181.

'BACKING' of wind explained, 31; reasons of, 78; why considered dangerous, 78, 148.

Balaclava storm, experience of, 138.

CHA

Ball, John, suggestion of storm warnings, 138, 139.

Barometer, corrections of, 2; — for capillarity, 2; — for capacity, 2; reduction of, to 32° F., 3; — to sea-level, 3; a single reading of, at any time, no indication of wind or weather, 27; scales, wording on, misleading, 49; rise and fall of, not infallible sign of weather, 53; instances of serious fall of with calm weather, 54.

Beaufort, Sir F., scale for wind, 8; notation of weather, 10.

Belt, Thomas, theory of origin of cyclones, 119.

Bennett, J. G., *New York Herald* warnings, 185.

Ben Nevis, difficulty of using reports from, 191.

Boussingault, M., on accumulated temperature, 199, 206.

Brisk, H.M.S., as signal-ship, 181.

Buy's Ballot, Prof., law of motion of wind, 26, 44.

CARLISLE, Bishop of, on failure of forecasts, 171.

Charts, weather, explained, 37.

CIR

- Circulation of wind with cyclones, 39; with anticyclones, 42.
 Cirrus-cloud observations, instructions for, 207; some results from, 215.
 Cirrus-clouds, value of, as signs of change of weather, 114.
 Clearness of atmosphere as sign of weather, 116.
 Clouds, deficiency of information respecting, in the Daily Weather Reports, 13; accompanying a cyclonic storm, 64.
 Co-existing depressions, 84.
 Collins, J. J., *New York Herald* warnings, 185.
 Crops, dependence of, on temperature, 196.
 Currents, equatorial and polar, 24.
 Curves from self-recording instruments at times of storm, 68, 75.
 Cyclone, typical, diagram of clouds and weather in, 65.
 Cyclones defined, 36, 58; illustrations of, 37, 58; typical, 62; passage of, on the northern side of a station, 68, 72; passage of, on the southern side of a station, 75; advance of, 65 *et seq.*; — probable rate of, unknown, 89; — affected by surface of ground, 95; — probable direction of, known to some extent, 95; — affected by conditions of pressure, 96.

DE CANDOLLE on accumulated temperature, 199.

Depressions defined, 36; very extensive, instance of, 54; secondary, 80; co-existing, 84. *See* Cyclones.

GAL

- Descending motion, effect of, on air, 57, 164.
 Districts of British Isles, arrangement of, 163.
 Draper, Prof. D., on storms crossing the Atlantic, 184.

EQUINOCTIAL gales, supposed recurrence of, disproved, Scott, 129; — Prince, 134; — in North Germany, 136; — in Adriatic, 136.

Evans, Lewis, first published statement of motion of storms, 87.

FALMOUTH Observatory, curves for February 2, 1873, 75; readings for same period, 223.

Faroe Islands, importance of information from, 182.

Faye, M., theory of origin of storms, 119.

FitzRoy, Admiral, institution of storm warnings, 140; storm-signal system, 119.

Fogs with anticyclones, 61.

Forecasts, FitzRoy, 162; Signal Office, Washington, 162; resumption of, in England, 162; preparation of, 165; hay harvest, 165; failure of, Oct. 24, 1882, 171; criticisms of, 174.

Forecasting, difficulty of, 163; results of, 168; — Ryves, 168; — Peek, 169.

Franklin, Benjamin, first recognition of motion of storms, 87.

GALE of Oct. 24, 1882, 172.

Gales, equinoctial, their recurrence disproved, 129.

GER

Germany, results of warnings from London to, 189.

Gilbert, Dr. J. H., on accumulated temperature, 196, 205

Gradients explained, 45, 53; instances of, 47, 52; for certain winds, 53; relation of, to winds, 55.

Gyration of wind, law of, stated, 30; explained, 77.

HAMBURG, warnings from London to, 189.

Harries, H., on storm of Oct. 24, 1882, 173.

Heart's Content, telegraphic reports from, value of, 183.

Hoffmeyer, on Atlantic weather, 187.

Hoffmeyer's charts, 96.

Humidity, importance of, as indication of weather, 6; changes of, during progress of storms, 70, 73, 76.

Humidity of air, action of ascending and descending motion on, 57, 164.

Hurricanes, 44, 88.

ICELAND, cost of proposed telegrams from, 183.

Isobars defined, 33; mode of drawing, 35.

KOEPPEN, Dr., on sun-spots and temperature, 123; — on periodicity of weather, 124.

LAW, Buys Ballot's, 26, 44; of Gyration, 30, 77; of Storms, 44, 137.

NEW

Lawes, Sir J. B., on accumulated temperature, 196.

Leverrier, M., first proposal of storm warnings in Europe, 138; ideas as to object of storm warnings, 139, 146.

Ley, Rev. W. Clement, theory of motion of storms, 118; diagram of typical cyclone, 65; cirrus-cloud observations, 207.

Loomis, Prof., on storms crossing the Atlantic, 184.

MELDRUM, C., theory of origin of storms, 119; periodicity of rainfall, 120.

Mistiness of atmosphere a sign of weather, 117.

Mohn, Prof., theory of origin of storms, 118.

Monsoons, 25.

Motion of cyclones in different directions, effects of, 78; probable rate of, comparatively unknown, 89; in relation to mountains, 95; in relation to distribution of pressure, 95 *et seq.*; erratic, instance of, 103.

Mountains, effects of, on motion of cyclones, 95; effects of, on winds, 179; effects of, on weather, 164.

Mountain stations, 190; — value of, Gen. Hazen, 191; — Prof. Mascart, 191.

Müller, Dr. R., on equinoctial gales, 136.

NEWFOUNDLAND, telegraphic reports from, value of, 183. *New York Herald* warnings, 185; — results of, 186.

PEE

PEEK, C. E., on results of forecasts, 169.

Periodicity of weather, 124; of storms, 129.

Pressure, relation of, to wind, 47; — to motion of cyclones, 99.

Prince, C. L., on equinoctial gales, 134.

RAIN, not properly indicated by telegraphic weather reports, 7; with cyclones, 67; with easterly winds, 77; — produced by ascending currents of air, 57, 164.

Rainfall, periodicity of, 120.

Rate of motion of storms, 89.

Redfield, discoverer of the Law of Storms, 137.

Reid, Law of Storms, 137.

Reports, telegraphic, defects of, 12.

Results of Storm Warnings for the British Isles, 152; of Forecasts, 168.

Reye, Prof., theory of origin of storms, 119.

Ryves, Rev. G. T., on results of forecasts, 168.

ST. KILDA, value of, as a possible reporting station, 182.

Sea disturbance, scale for, 11; value of, as indication of weather, 11.

Sea-level, reduction of barometrical readings to, 3.

Secondary depressions, instances of, 80; effects of, on their primaries, 82.

Shower, with shift of wind to north-west, 65, 72.

TEM

Signal-ships, proposal of, 15, 181; — proved to be possible, 181.

Signals, storm, explanation of, 142.

Signs of storm, 146.

Storms, definition of, 8; with high barometer, 27; vertical depth of, slight, 29; advance of, 87; rate of advance of, unknown, 89; probable direction of advance of, 95 *et seq.*; advance of, over the Atlantic, 15, 118, 184; — distribution of, in the British Isles, 127.

Storm warnings, institution of, 138; difficulty of issuing correct, 148; results of, 152; — suggestion of, Ball, 138; Leverrier, 138.

Strachey, Gen. R., on calculation of accumulated temperature, 199.

Straight-line gales, explanation of, 28.

Summary of principles recognised in weather study, 110.

Sunday interruption to weather reports, 15.

Sunk light-ship connected with Harwich, 181.

Sun-spots, relation of, to rainfall, 121-5; — and temperature in England, 123; — over the globe, 123.

TEMPERATURE, correction of barometer for, 3; information respecting, given in Daily Weather Reports, 5; mean, definition of, 5; — mode of ascertaining, 5; instances of sudden falls of, 65, 76; regular daily course of, disturbed by storms, 70, 73; differ-

THE

ences of, as sign of storm, 149;
 — accumulated, calculation of,
 196; effect of, on crops, 196.
 Thermometer, attached, 2; wet and
 dry bulb, 6.
 Tornado in Sweden, 29.
 Trade winds, 24.
 Typhoons, 44, 88.

VALENCIA Observatory, curves
 for March 27, 1874, 69; read-
 ings for same period, 221.
 Veering of wind explained, 31;
 reasons of, 78.

WARNINGS, storm, first pro-
 posal of, in America, 136;
 first proposal of, in Europe, 138;
 first proposal of, in England, 139;
 results of, for Hamburg, 189;
 results of, for the United King-
 dom, 152; instances of failure of,
 154, 161.

Washington, Chief Signal Office,
 14, 179, 188.

Weather, Beaufort notation for, 10;
 value of reports of general ap-

WOR

pearance of, 12; charts, explana-
 tion of, 33; with anticyclones,
 58, 59; with cyclones, 58, 62;
 charts, mode of using, 113; local
 characteristics of, 115; — periodi-
 city of, Köppen, 124.

Weather Reports in 1887, specimen
 of, 18; in 1874, specimen of,
 218.

Weekly Weather Report, institution
 of the, 193.

Wind, Beaufort scale for, 7; cannot
 well be measured instrumentally
 at telegraph stations, 8; measure-
 ment of, by velocity instead of
 pressure, 9; characteristics of
 main currents of, 23; currents,
 polar and equatorial, 24; Trade,
 25; Buys Ballot's law for, 26;
 motion of, in cyclones, 40; mo-
 tion of, in anticyclones, 42;
 cause of, 45; relation of, to gra-
 dients, 52; reports of, from tele-
 graphic stations sometimes de-
 ceptive, 148.

Wording on barometer scales, mis-
 leading, 49.

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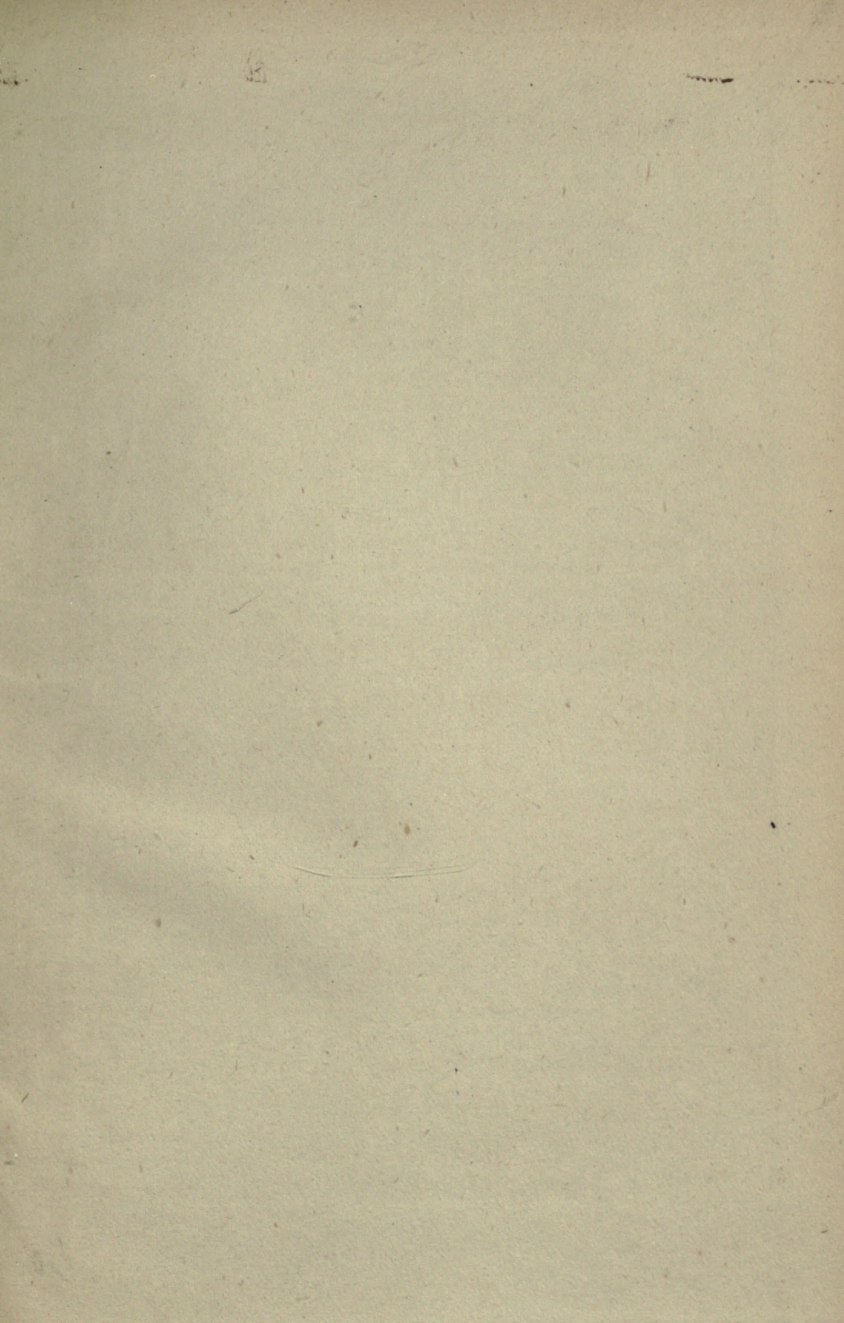
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